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Acaricide Dusts on Vegetable and Field Crops in Southern California, 1949–1950[1,2]

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Control of mites attacking vegetable and field crops has become one of the most important problems confronting farmers in southern California. In the last few years many new acaricides have been developed. The experiments reported here were conducted to evaluate the efficiency of some of the new acaricides on mite species damaging various crops under different environmental conditions in this area.

Observations made over a period of 3 years (1949–51) indicate that the most important species of mites on vegetable and field crops in southern California are the two-spotted spider mite, *Tetranychus bimaculatus* Harvey; the closely related species *T. multisetis* McGregor; and the strawberry spider mite, *T. atlanticus* McGregor. *T. pacificus* McGregor and *Petrobia latens* (Müller) are damaging in some areas, but in this paper only the first three species of *Tetranychus* listed above will be discussed.

Injury caused by these mites often begins in a small area on the field margin or alongside an adjacent dusty road and then spreads through the field, usually traveling most rapidly downwind. Plant damage generally begins with small colonies of mites on the undersides of the lower or older leaves. As a colony increases in size, the mites move out or up on the plant. If the infestation becomes severe, copious amounts of webbing are spun over the leaf surface and may completely enshroud the leaf. Eventually, the leaf dries and may fall off the plant. If the damage continues unchecked, entire plants may be killed.

Materials and Methods.—The crops upon which acaricide tests have been made are snap beans, lima beans, watermelons, Kenland red clover (grown for seed), cantaloupes, and seed alfalfa. Since many of the recently developed acaricides have very little or no fumigation effect, thorough plant coverage is necessary. On a great many vegetable and field crops good coverage with sprays is impracticable or difficult to obtain. Because of this, and for preliminary evaluation, the following acaricides were tested for effectiveness as dusts:[6]

1. 2-(*p*-tert-butylphenoxy) isopropyl 2′-chloroethyl sulfite[7]
2. *p*-chlorophenyl *p*-chlorobenzenesulfonate (*Compound K-6451*)[8]
3. *p*-chlorophenyl phenyl sulfone (*Compound R-242*)[9]
4. 2,4-dichlorophenyl benzene sulfonate (*Compound 923*)[10]
5. 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate[11]
6. S-carbamylmethyl-0,0-dimethyl dithiophosphate[11]
7. 0-ethyl 0-*p*-nitrophenyl benzenethiophosphonate (EPN)[12]
8. 2,3,3a,4,5,6,7,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene-1-one[10]
9. S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (malathon)[11]
10. Tetraethyl pyrophosphate
11. Parathion[11]
12. Dinitro caprylphenylcrotonate[12]
13. DMC[13]
14. Sulfur

[1] Paper No. 715, University of California Citrus Experiment Station, Riverside, California.

[2] Presented at the Meeting of the American Association of Economic Entomologists, Denver, Colorado, December, 1950.

[3] Univ. Citrus Experiment Station, Riverside.

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[5] Appreciation is expressed to J. W. Hashe, T. O. Tuft, and R. M. Hannibal, who generously assisted in the numerous applications and mite counts in these tests, and to the growers who permitted use of their fields.

[6] For convenience in referring to some of these acaricides, the designations shown in parentheses are used in this paper.

[7] *Aramite;* Naugatuck Chemical Division, United States Rubber Company.

[8] *Ovotran;* The Dow Chemical Company.

[9] *Sulphenone;* Stauffer Chemical Company.

[10] General Chemical Company.

[11] American Cyanamid Company.

[12] *Karathane;* Rohm and Haas Company.

[13] The Sherwin-Williams Company.

Table 1.—Effects of various acaricide dusts on control of *Tetranychus multisetis* on snap (pole) beans near Chula Vista, California, in 1949.

Treatment[1]	Dosage (Pounds per Acre) Applied Nov. 21	Mite Counts on 80-Leaf Samples				
		After 9 Days (Nov. 30)		After 16 Days (Dec. 7)		
				Adult Mites		
		Adult Mites	Leaves Having 0–5 Nymphs	Number	Per Cent Reduction from Check	Leaves Having 0–5 Nymphs
Check (untreated)	—	—	—	327	—	5
Compound R-242, 10%[2]	88	38	75	47	86	77
Aramite, 5%[3]	88	43	73	72	78	57
Compound K-6451, 10%[4]	88	139	69	115	65	70
Compound 923, 10%[5]	88	99	71	155	53	71
DMC, 2.5%[6]	76	144	55	158	52	54
S-carbamylmethyl-0,0-dimethyl dithiophosphate, 1%	98	38	68	199	39	36
0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate, 1%	88	53	73	215	34	47
Dinitro caprylphenylcrotonate, 3.5%	66	283	58	259	21	38

[1] All dusts were blended from wettable powders, with pyrophyllite as diluent.
[2] *p*-chlorophenyl phenyl sulfone.
[3] 2-(*p*-tert-butylphenoxy) isopropyl 2′-chloroethyl sulfite.
[4] *p*-chlorophenyl *p*-chlorobenzenesulfonate.
[5] 2,4-dichlorophenyl benzene sulfonate.
[6] 4,4′-dichloro-alpha-methyl benzhydrol.

All the materials tested were applied as dusts by means of rotary hand dusters, using two nozzles. To obtain thorough plant coverage, several methods of application were employed. As the lima beans and Kenland red clover were planted in rows, the duster was operated so that each nozzle covered one side of the row. For applications on watermelons, cantaloupes, and alfalfa, the operator walked slowly, moving the nozzles from side to side, so as to cover the plants completely. In order to obtain complete coverage of the snap (pole) beans, which were about 6 feet high and heavy with foliage, the operator moved the two nozzles up and down the plants and treated both sides of each row.

In all the tests each treatment was replicated four or five times, and the various replicates were randomized.

The effectiveness of the various treatments was measured by counting the number of mites per unit area of lower leaf surface. In each experiment leaf samples were collected in each replicate, and the total number of leaves examined for each treatment ranged from 60 to 100.

The leaves taken from each replicate were put in a small paper bag, which was placed in a portable ice box in the field and later transferred to a refrigerated room in the laboratory. This procedure kept the leaves fresh and the mites alive, so that counts could be made in the laboratory from 1 to 3 days after collections.

Mite counts on leaves of snap (pole) beans, lima beans, cantaloupes, and watermelons were made by stamping a circular area (0.6 square inch) out of each leaf with seven-eighths inch-diameter punch, and counting the mites in that area. In each experiment approximately the same location in each leaf was stamped out. In the test on Kenland red clover, all the mites on the underside of the center leaflet of the trifoliate leaf were counted, and on alfalfa the mites on the underside of the entire trifoliate leaf were counted.

SNAP (POLE) BEAN TESTS.—These experiments were conducted in the Chula Vista area of San Diego County. The mite species was *Tetranychus multisetis* McGregor.

Tests in 1949.—Each treatment in the 1949 tests was replicated five times, and each replicate of each treatment was one row wide and 50 feet long. Because the fifth replication had a very low mite population, mite samples were taken from only four replications. Twenty leaves were examined per replicate, or a total of 80 leaves per treatment. Treatment was made on November 21, and mites were

Table 2.—Effects of various acaricide dusts on control of *Tetranychus multisetis* on snap (pole) beans near Chula Vista, California, in 1950.

Treatment[1]	Dosage (Pounds per Acre) Applied		Mite Counts on 100-Leaf Samples[2]				
	Sept. 28	Oct. 19	Oct. 13	Oct. 25	Nov. 1	Nov. 8	Per Cent Reduction from Check Nov. 8
Check (untreated)	—	—	340	333	1255	2171	—
Compound K-6451, 10%[3]	83	109	97	22	21	43	98.1
Aramite, 2%[4]	83	109	93	190	288	274	87.4
Parathion, 2%	62	78	173	100	234	316	85.4
Parathion, 1%	62	109	177	212	265	377	82.6
Malathon, 5%[5]	68	114	161	173	281	323	85.1
Compound R-242, 10%[6]	62	83	191	174	271	447	79.7
Compound 923, 10%[7]	83	73	239	103	263	749	65.5
Sulfur	104	78	160	312	1014	793	63.5
2,3,3a,4,5,6,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene-1-one	88	88	339	334	1492	1412	34.8

[1] Unless otherwise specified, all dusts except sulfur were blended from wettable powders, with pyrophyllite as diluent.
[2] Counts represent total number of adult and immature mites.
[3] *p*-chlorophenyl *p*-chlorobenzenesulfonate.
[4] 2-(*p*-tert-butylphenoxy) isopropyl 2'-chloroethyl sulfite, a commercially prepared impregnated material.
[5] S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate.
[6] *p*-chlorophenyl phenyl sulfone.
[7] 2,4-dichlorophenyl benzene sulfonate.

counted on November 30 and December 7. Further counts were not made because the plants were killed by freezing weather. The materials used and results obtained are summarized in table 1.

In these tests, 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate, S-carbamylmethyl-0, 0-dimethyl dithiophosphate and *Compound R-242* and Aramite gave excellent mite reductions in 9 days. At the end of 16 days the phosphate materials were not maintaining mite control (39 per cent and 34 per cent reduction from check, respectively), but *Compound R-242* and Aramite were still giving good control (86 per cent and 78 per cent reduction, respectively). *Compounds K-6451* and *923* and DMC gave fair mite reduction in 9 days, and in 16 days the control was still only fair (52 to 65 per cent reduction). It is significant, however, that areas treated with *Compound K-6451* showed better control at 16 days than at 9 days. Dinitro caprylphenylcrotonate gave poor mite control.

1950 Tests.—Each treatment in the 1950 tests was replicated four times and each replicate was three rows wide and 50 feet long. Two applications were made, the first on September 28 and the second on October 19. Samples of 25 leaves were taken from the center row of each replicate, and a total of 100 leaves was examined for each treatment. Counts were made on October 13 and 25, November 1 and 8. The materials used and the results obtained are summarized in table 2.

Compound K-6451 gave outstanding control (98.1 per cent reduction from check) in these tests. This material is effective primarily against eggs and/or newly hatched mites (Jeppson *et al.* 1950), and because of its long residual activity it appears to be most effective when used as a preventive measure. Aramite gave good control (87.4 per cent). One of the four replicates of this treatment was subject to a heavy mite migration from an adjoining bean field, but the other three replicates showed as

Table 3.—Effects of various acaricide dusts on flavor rating of snap (pole) beans cooked at different intervals (15 and 34 days) after final treatment (1950 tests).

Treatment, Sept. 28 and Oct. 19[1]	Total Numerical Flavor Rating[2] by	
	26 Panel Members, Nov. 3	39 Panel Members, Nov. 22
Check (untreated)	187	250
Aramite, 2%	196	258
Compound R-242, 10%	185	257
Malathon, 5%	182	275
Parathion, 2%	181	276
Compound K-6451, 10%	171	260
Compound 923, 10%	78	237
Difference required for significance at 5% level	27	Not significant

[1] For description of treatments, refer to Table 2.
[2] Flavor rated from 1 (very poor) to 10 (excellent) (Hening 1948).

good control as the areas treated with *Compound K-6451*. Parathion (both 1 per cent and 2 per cent), malathon, and *Compound R-242* all gave good control (80 to 85 per cent reduction from check). *Compound 923* and sulfur gave only fair control (65.5 per cent and 63.5 per cent, respectively), and 2,3,3a,4,5,6,7,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methano-indene-1-one gave poor control (34.8 per cent).

Flavor Tests.—Flavor tests were conducted with beans picked from the acaricide plots of the 1950 snap (pole) bean-experiment. The field was dusted on September 28 and October 19, and the beans were picked for flavor tests 15 and 34 days after the last treatment. Both tests were conducted 2 days after picking. The pans, amounts of water, and seasoning used in cooking were identical. Flavor was rated from 1 to 10, as follows: 1 to 2, very poor; 3 to 4, poor; 5 to 6, fair; 7 to 9, good; and 10, excellent (Hening 1948). The results tabulated by two taste panels of 26 and 39 members, respectively, are shown in table 3. These results were analyzed statistically, and 15 days after the second treatment only beans from the plots treated with *Compound 923* showed significant off-flavor. Thirty-four days after treatment none of the treated beans were significantly poorer in flavor than the untreated.

KENLAND RED (SEED) CLOVER TESTS.—Acaricide dusts were applied for control of the two-spotted spider mite, *Tetranychus bimaculatus*, on Kenland red clover in the Hemet area of Riverside County. Each treatment was replicated four times and each replicate was two rows wide and 50 feet long. Mite counts were made on 20 leaflets collected per replicate, or a total of 80 leaflets per treatment. The materials used and the results obtained are summarized in table 4.

In this test Aramite gave outstandingly good mite control at 21 days (97.1 per cent reduction from check). *Compounds R-242* and *K-6451* gave mite reductions of 78.4 per cent and 74.2 per cent, respectively. In the plots treated with *Compound K-6451*, the control was much better at 21 days after treatment than at 7 days. *Compound 923* gave poor control.

CANTALOUPE TESTS.—Acaricides were applied for control of the strawberry spider mite, *Tetranychus atlanticus*, in the Imperial Valley. Because many of the cantaloupe varieties grown in this area are not injured by sulfur dust, to which this mite is very sensitive, there is no control problem on these varieties. Several varieties that are susceptible to injury by sulfur have better-quality melons, however, and since mite control is essential on these varieties, the following tests were run on sulfur-susceptible cantaloupes.

Two applications were made, on May 5 and 19, to plots one row wide and 40 feet long. Each treatment was replicated four times. Twenty-five leaves were collected from each replicate, or a total of 130 leaves per treatment. Mite counts were made on May 16 and 25. The materials used and results obtained are shown in table 5.

When used against *Tetranychus atlanticus* on cantaloupes, *Compounds R-242* (5 and 10 per cent), *K-6451* (10 per cent),

Table 4.—Effects of various acaricide dusts on control of *Tetranychus bimaculatus* on Kenland red (seed) clover near Hemet, California, in 1950.

Treatment[1]	Dosage (Pounds per Acre) Applied Aug. 22	Counts on 80-Leaflet Samples After— 7 Days (Aug. 29) Adult and Immature Mites	Leaflets Having 0–5 Eggs	21 Days (Sept. 12) Adult and Immature Mites	Leaflets Having 0–5 Eggs	Per Cent Reduction from Check
Check (untreated)	—	2980	31	2595	42	—
Aramite, 2%[2]	40	135	80	76	80	97.1
Compound R-242, 10%[3]	40	516	73	559	70	78.4
Compound K-6451, 10%[4]	31	1115	54	617	73	74.2
Compound 923, 10%[5]	31	1165	48	1563	49	39.8

[1] Unless otherwise specified, all dusts were blended from wettable powders, with pyrophyllite as diluent.
[2] 2-(*p*-tert-butylphenoxy)isopropyl 2′-chloroethyl sulfite, a commercially prepared impregnated material.
[3] *p*-chlorophenyl phenyl sulfone.
[4] *p*-chlorophenyl *p*-chlorobenzenesulfonate.
[5] 2,4-dichlorophenyl benzene sulfonate.

Table 5.—Effects of various acaricide dusts on control of *Tetranychus atlanticus* on cantaloupe vines in the Imperial Valley, California, in 1950.

Treatment[1]	Dosage (Pounds per Acre) Applied		Total Adult and Immature Mites on 100-Leaf Samples		
	May 5	May 19	May 16	May 25	Per Cent Reduction from Check May 25
Check (untreated)	—	—	1298	2595	—
Compound R-242[2]					
10%	38.0	49.9	28	14	99.5
5%	38.0	61.8	73	14	99.5
Compound K-6451, 10%[3]	35.5	49.9	187	22	99.2
Aramite[4]					
1%[5]	33.2	49.9	372	1216	53.2
2%[5]	36.7	42.8	80	48	98.2
5%	47.5	49.9	695	865	66.7
Compound 923, 10%[6]	39.2	47.5	302	88	96.6
TEPP, 1%[7]	34.5	40.4	254	204	92.1
Parathion, 1%	38.0	57.0	492	365	85.9
EPN, 1%[8]	38.0	47.5	712	1815	30.0
DDT, 5%	33.2	28.5	1864	3529	+26.4

[1] Unless otherwise specified, all dusts were blended from wettable powders with pyrophyllite as diluent.
[2] *p*-chlorophenyl phenyl sulfone.
[3] *p*-chlorophenyl *p*-chlorobenzenesulfonate.
[4] 2-(*p*-tert-butylphenoxy) isopropyl 2'-chloroethyl sulfite.
[5] Commercially prepared impregnated dust.
[6] 2,4-dichlorophenyl benzene sulfonate.
[7] Commercial preparation of tetraethyl pyrophosphate.
[8] Commercial preparation of 0-ethyl 0-*p*-nitrophenyl benzenethiophosphonate.

Aramite (2 per cent), *923* (10 per cent) and TEPP (1 per cent) gave excellent control, with a reduction from check of 92.1 to 99.5 per cent. Parathion (1 per cent) gave good control (85.9 per cent reduction). It is interesting to note that 1 per cent Aramite as an impregnated dust gave almost as good mite control as the 5 per cent material blended from a wettable powder (53.2 per cent and 66.7 per cent reduction from check, respectively). EPN dust (1 per cent) gave poor control, and a larger mite population occurred in the DDT-dusted blocks than in the untreated. In this cantaloupe field the vines were eventually killed by mites, except where *Compounds R-242*, *K-6451*, Aramite, or *923* were used.

Under the high temperatures of this desert area (100° F. or higher), all treatments with *Compounds R-242*, *88R*, *K-6451*, and *923* caused a slight amount of plant injury when applied by hand dusters. Observations made subsequently have indicated that these materials cause no injury when applied uniformly by power dusters or airplanes.

WATERMELON TESTS.—An acaricide test for control of a mixed population of mites (*Tetranychus bimaculatus* and *T. multisetis*) on watermelons was conducted near Hemet. The vines at time of application were large and covered the ground completely. Each treatment was replicated four times, and each replicate was one row wide and 30 feet long. Twenty leaves per replicate were collected, or a total of 80 leaves per treatment. Treatments were made on September 6 and 25. The acaricides used and the results obtained are shown in table 6.

In these tests Aramite was the only material that gave excellent mite control (94.7 per cent reduction from check). *Compounds R-242* and *K-6451* gave only fair control (69.2 per cent and 64.2 per cent, respectively). Control with 2 per cent parathion was poor (47 per cent) but much better than that with 1 per cent parathion. EPN and *Compound 923* gave very poor control. Indications from these tests and the Kenland red clover tests are that Aramite gives considerably better control of *Tetranychus bimaculatus* than the other materials tested.

ALFALFA TESTS.—Acaricide tests for control of *Tetranychus atlanticus* on seed alfalfa in the Imperial Valley gave poor results with all the materials used except sulfur. This undoubtedly was caused by poor plant coverage, and it indicates that for mite control tests on this crop, power

Table 6.—Effects of various acaricide dusts on control of *Tetranychus bimaculatus* and *T. multisetis* on watermelon vines near Hemet, California, in 1950.

Treatment[1]	Dosage (Pounds per Acre) Applied		Total Adult and Immature Mites on 80-Leaf Samples		
	Sept. 6	Sept. 25	Sept. 14	Oct. 11	Per Cent Reduction from Check Oct. 11
Check (untreated)	—	—	374	1262	—
Aramite, 2%[2]	50	50	35	67	94.7
Compound R-242, 10%[3]	37.5	37.5	101	390	69.2
Compound K-6451, 10%[4]	50	37.5	178	452	64.2
Parathion,					
2%	37.5	50	372	670	47.0
1%	37.5	37.5	508	2322	+84.0
EPN, 2%[5]	50	50	384	1169	7.5
Compound 923, 10%[6]	37.5	37.5	174	1220	3.4

[1] Unless otherwise specified, all dusts were blended from wettable powders, with pyrophyllite as diluent.
[2] Commercially prepared impregnated dust of 2-(*p*-tert-butylphenoxy) isopropyl 2'-chloroethyl sulfite.
[3] *p*-chlorophenyl phenyl sulfone.
[4] *p*-chlorophenyl *p*-chlorobenzenesulfonate.
[5] 0-ethyl 0-*p*-nitrophenyl benzene thiophosphonate.
[6] 2,4-dichlorophenyl benzene sulfonate.

equipment must be used. Sulfur, even though coverage was poor, gave better than 99 per cent control 8 days after treatment, and 23 days after treatment mite control (reduction from check) was still about 97 per cent. Maximum temperatures at the time of this experiment, in June, were about 100° F.

LIMA BEAN TESTS.—These tests were performed in Orange County, and the effects of 14 acaricides were compared. The Lima bean plants were mature, and the farmer was allowing the field to dry for harvest. The dry condition of these plants, combined with mite damage, caused a heavy plant defoliation before enough time had elapsed for adequate evaluation of mite control. In general, *Compounds K-6451* and Aramite looked promising for mite control on this crop.

SUMMARY AND CONCLUSIONS.—The three most important species of mites attacking vegetable and field crops in southern California are *Tetranychus bimaculatus* Harvey, *T. multisetis* McGregor, and *T. atlanticus* McGregor.

Fourteen acaricide dusts applied by two-nozzle rotary hand dusters were tested during 1949 and 1950 for effectiveness in controlling these mites on various crops as follows: *Tetranychus multisetis* on snap (pole) beans, lima beans, and watermelon vines; *T. bimaculatus* on watermelon vines and Kenland red (seed) clover; and *T. atlanticus* on alfalfa and cantaloupes.

The compound 2-(*p*-tert-butylphenoxy) isopropyl 2'-chloroethyl sulfite (Aramite) gave excellent initial and residual control of the three mite species and was outstandingly better than the other materials tested against *Tetranychus bimaculatus*. The 2 per cent impregnated material was far superior to the 5 per cent material blended from wettable powder. Results with the 1 per cent impregnated compound were poor.

Ten per cent *p*-chlorophenyl *p*-chlorobenzenesulfonate (*Compound K-6451*) appeared to give best control when used as a preventive dust. Although this compound gave low initial kill, it showed long residual activity. It gave excellent control of *Tetranychus atlanticus* and *T. multisetis* but was somewhat inferior to Aramite when used against *T. bimaculatus*.

Ten per cent *p*-chlorophenyl phenyl sulfone (*Compound R-242*) gave only fair to good control of both *Tetranychus bimaculatus* and *T. multisetis*, but gave excellent control of *T. atlanticus*, at least under the high-temperature conditions of inland and desert areas.

Mite control with 2,4-dichlorophenylbenzene sulfonate (*Compound 923*) was inconsistent. Control of *Tetranychus atlanticus* in hot desert areas was excellent with this compound, but against *T. bimaculatus* it gave poor results. It gave fair control of *T. multisetis*.

In general, all the phosphate materials tested, except EPN, gave good initial

mite reductions, but the residual activity was of short duration. This probably indicates the need of two applications, with the second timed so as to kill the mites hatching from eggs that were present at the time of the first application. When 1 per cent, 0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate and S-carbamylmethyl-0,0-dimethyl dithiophosphate were tested on *Tetranychus multisetis*, the initial reduction was good, but 16 days later control was poor. Two treatments, three weeks apart, of 5 per cent S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate and of 1 and 2 per cent parathion, gave good control of *T. multisetis* in relatively cool coastal areas. Two treatments of both 1 and 2 per cent parathion, 19 days apart, gave poor control of a mixed population of *T. multisetis* and *T. bimaculatus* at warm temperatures; but against *T. atlanticus* in the hot desert areas two treatments of 1 per cent parathion, 14 days apart, gave good control. Two treatments of 1 per cent tetraethyl pyrophosphate gave good control of *T. atlanticus* in the desert.

Sulfur gave nearly perfect control of *Tetranychus atlanticus* in the hot inland areas, but in cooler areas it gave only fair control of *T. multisetis*. One per cent EPN does not appear to be effective in a dust form. Dinitro caprylphenylcrotonate (3.5 per cent) and 5 per cent 2,3,3a,4,5,6,7,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methano-indene-1-one gave poor control on *T. multisetis*. When 4,4′-dichloro-alpha-methyl benzhydrol DMC was used at 2.5 per cent as a dust blended from wettable powder, it gave only fair control of *T. multisetis*.

In general, of the three mite species, *Tetranychus atlanticus* appears to be the most susceptible to the control measures used in these tests, and *T. bimaculatus* appears to be the least susceptible.

Flavor tests were conducted on snap (pole) beans dusted twice with *Compounds R-242*, malathon, *p*-chlorophenyl *p*-chlorobenzenesulfonate (*K-6451*), 2,4-dichlorophenyl benzene sulfonate (*923*), 2-(*p*-tert-butylphenoxy) isopropyl-2′-chloroethyl sulfite (Aramite), and parathion. Fifteen days after the last treatment, only beans from areas treated with 2,4-dichlorophenyl benzene sulfonate showed significant off-flavor after cooking. Thirty-four days after the last treatment none of the beans tested indicated off-flavor.

At high desert temperatures (100° F. or higher), *Compounds R-242*, 2,4-dichlorophenyl benzene sulfonate (*923*), *p*-chlorophenyl *p*-chlorobenzenesulfonate (*K-6451*), and Aramite produced a slight amount of injury on cantaloupe vines. Subsequent observations have indicated that these materials cause no injury when applied uniformly by ground or aerial dusters.

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Mites on Melons in Northern California

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Among the principal pests attacking melons in northern California are mites belonging to the genus *Tetranychus*, the most important and destructive species of which is the Pacific mite, *T. pacificus* McG.

In our investigations it was soon recognized that destructive mite populations frequently followed where DDT had been applied to control cucumber beetles, *Diabrotica undecimpunctata* Mann. and *Acalymma trivittata* (Mann.) or the melon leafhopper, *Empoasca abrupta* DeLong. In some cases the mites became so abundant that the crop was severely injured and the leaves were completely covered with webbing. Also, on occasions the melon aphid, *Aphis gossypii* Glov., increased to destructive levels, and the combined loss from these two pests would tend to neu-

Table 1.—Treatments and per cent of honeydew melon leaves showing mite infestation. (Treated July 9 and 25.)

Survey Date	Check	Concentrated Sprays[1]		Dusts[2]			
		0.75 Lb. Dieldrin	1.00 Lb. Heptachlor	2.5% Aldrin	3% Heptachlor	5% TM-1	3% DDT-50% Sulfur
July							
12	0	1	0	0	1	0	2
19	1	1	0	0	0	1	0
24	1	0	1	0	1	6	0
30	1	5	3	1	3	3	1
August							
6	0	2	2	3	4	5	0
13	2	7	6	11	2	2	0
20	4	18	19	27	9	14	6
27	6	46	45	37	29	32	9

[1] Amounts of actual toxicant applied in 20 gallons of water per acre per application.
[2] Rate varied from 20 to 30 pounds per acre per application.

tralize any advantage obtained from the control of cucumber beetles and the melon leafhopper with DDT.

The relation of DDT to the melon aphid and its place in the melon insect control program has been reported upon by Michelbacher & Middlekauff (1950). The most obvious reason for the increase in the pest populations following applications of DDT appears to be a serious disruption of the host-natural enemy balance. This, however, is probably not the entire explanation for there is some evidence which indicates that DDT may alter factors in the environment in some physical or physiological manner favorable to the mite. At least there are cases where it is rather difficult to account for the increase in the pest population due solely to the destruction of natural enemies. Where natural conditions are unfavorable for mite development applications of DDT and related insecticides are not always followed by serious increases in the mite population. Also, serious mite infestations are not always associated with the use of newer insecticides. Dryness favors mite development, and every effort should be made to keep melon fields in a vigorous growing condition. However, vegetative growth should not be stimulated to the point where it will have a definitely adverse effect upon the quality of the melons. Serious mite infestations may result from melon fields being adjacent to other crops that are heavily infested with mites, or, infected weeds growing along roads, ditch banks and similar locations may be the source of destructive populations. Dust has long been known to stimulate mite activity, and frequently very serious infestations develop along dusty roads or lanes.

Because DDT is so effective in the control of cucumber beetles, darkling ground beetles, and the melon leafhopper, investigations have been directed towards developing an insect control program in which it can be safely used. Soon after the advent of DDT it became evident that serious increases in the mite population were encouraged by frequent applications of this insecticide. Further, it was observed that there was some correlation between the dosage used and the seriousness of the infestation. Based upon this information, experiments were conducted to determine the minimum number of applications and the lowest possible dosage that could be used to insure effective control of undesirable pests.

In order to reduce the number of DDT applications, it was found advisable to treat the developing melon plants with cryolite during the early stages of growth to control cucumber beetles and refrain from applying DDT until the melon leafhopper population reached a level that would justify control. This recommendation was made despite the fact that DDT is much more effective against cucumber beetles than is cryolite. The use of DDT earlier in the program, however, may be justified where the cucumber beetle population is extremely large or where the young plants are being seriously injured by thrips. If used at this time DDT should be lightly but thoroughly applied.

As far as dosage is concerned, it was determined that exceptionally good control of the melon leafhopper could be obtained with an amount not to exceed 1

pound of actual DDT per acre. At this level the danger of an increase in the mite population is not eliminated but it is much reduced below that which is likely to occur where larger dosages are applied. In order to hold the number of DDT applications to a minimum, it is necessary that exceptionally good control of the melon leafhopper and cucumber beetles be obtained with each application. These pests should be all but eliminated from treated fields, and this goal can be obtained only where the insecticide is thoroughly and evenly applied under suitable weather conditions. This means that efficient equipment must be used. Poor kills often result in a rapid increase in the pest population, making frequent treatments necessary. This is likely to result in the development of a destructive mite population. Depending upon the season and locality not more than from one to three DDT treatments for leafhopper control should be necessary. Applications of DDT made late in the growth of the crop are not likely to result in as much harm as those applied earlier. The reason for this is that following late applications the mite population may not have sufficient time to develop to a destructive level before the crop is harvested.

There is some correlation between the time of the season DDT and related insecticides are applied and the seriousness of the mite infestation. Usually the later the applications the less the injury. Thus more destruction from mites would be expected from July and August applications than from those made during September or later. This can be explained by the fact that temperatures during early and midsummer are more favorable for mite activity than those occurring during September and later.

The tendency of chlorinated hydrocarbon insecticides to permit increase of mite infestation was demonstrated in experiments conducted in 1951. The results in all tests, which included several varieties of melons, were similar and the information obtained in one series is shown in table 1. It is seen that the trend in the number of leaves infested with mites was greater where plots of honeydew melons were treated with aldrin, dieldrin, heptachlor or Q-137, an analog of DDT, than it was in untreated plots or in those treated with DDT and sulfur. It should be pointed out that the incorporation of sulfur with DDT will greatly reduce the danger of a serious mite infestation developing. This combination has limited use as most melon varieties other than honeydew are injured by sulfur. However, where dusts of DDT or related insecticides are applied to honeydew melons it is recommended that they contain at least 50 per cent sulfur.

Table 2.—Average number of mites per sample of leaf where honeydew melons were treated with several insecticides on August 20.

Survey Date	Check[1]	Concentrated Spray[2]	
		Dieldrin 0.5 Lb.	Aldrin 1.0 Lb.
Sept. 12	0.37	6.61	5.82
Sept. 17	3.58	26.57	13.40
Sept. 24	17.64	32.10	30.20
Oct. 8	27.23	5.41	22.60

[1] Previous to August 20, dusted with 3 per cent DDT-50 per cent sulfur at the rate of 30 pounds per acre.
[2] Amounts of actual toxicant applied in 20 gallons of water per acre.

In one of the 1951 experiments mite counts from leaf samples were made where plots treated with dieldrin and aldrin were compared to plots treated with a mixture of DDT and sulfur. The samples for mite counts were obtained by picking 25 mature leaves at random from the center rows of each treatment. On each leaf three impressions were made at random with a number 10 cork borer (15 mm. in diameter) and the mites in all stages of development, except the egg, in these marked areas were counted. In other experiments here reported the above technique for population determination was used. The information for the 1951 experiment concerning treatments and the average number of mites per sample is given in table 2. The data clearly show that the mite population increased more rapidly in the aldrin and dieldrin treatments than it did in the plot receiving DDT-sulfur. The latter, however, showed a higher population density on the final survey which was conducted on October 8. This can be explained by the fact that the leaves in the dieldrin and aldrin treatments had been fed on to a point where they could no longer support a large population, while those in the DDT-sulfur plot were still green and in a suitable condition for mite development and multiplication.

Where the melon aphid has become a problem a 1 per cent tetraethyl pyro-

Table 3.—Average number of mites per sample in check and plots treated on August 15 with 3 per cent aramite at approximately 33 pounds per acre.

Survey Date	Treatment	
	Check	3% Aramite
August 15[1]	39.0	39.0
August 17	19.0	8.8
August 24	27.0	4.6
August 31	32.0	2.1
September 5	46.0	7.0

[1] Pre-treatment count.

phosphate or a 2 per cent parathion dust has frequently been used to control it. Both of these insecticides suppress the mite population when thoroughly and evenly applied by ground machines at the rate of about 30 pounds per acre. They render an effective kill of all but the egg stage. If a second application is made in 7 to 10 days, the newly hatched mites are killed before they have had an opportunity to mate and lay eggs. The mite infestation where applications have been properly applied will have been reduced to a very low non-destructive level. However, if the insecticides are poorly applied there is a possibility that the mite will increase to destructive proportions in a very short period of time. Even where tetraethyl pyrophosphate dusts are thoroughly applied poor control may result if the melon vines at time of treatment are heavily wet with dew. The probable reason for this is that in the presence of moisture the tetraethyl pyrophosphate hydrolyzes before it has had an opportunity to produce a satisfactory kill. Because parathion is not affected in this manner it can be applied under a wider range of weather conditions than can tetraethyl pyrophosphate

On occasions serious mite infestations develop even where a careful insecticidal program has been followed. In order to be able to cope with this problem extensive investigations with acaricides were conducted in 1950 and 1951. The material most extensively used in 1950 was aramite. In a number of cases satisfactory control of mites was obtained with this material where a 3 per cent dust was applied by ground rig at the rate of about 30 pounds per acre. The results obtained in one experiment are given in table 3. The 3 per cent treatment held the mite population in excellent control for a period of at least 3 weeks. Melon vines in the check suffered serious injury.

Table 4.—Dust treatments, and average number of mites per sample of honeydew melon leaf on survey dates given. Treatments applied August 10, 1951.

Survey Date	Treatment				
	Check	10% Ovotran	7.5% Ovotran 3% DDT 50% Sulfur	3% 88R	3% 88R 3% DDT
Aug. 10	2.60	—	—	—	—
Aug. 14	4.47	1.76	1.80	1.40	0.74
Aug. 24	4.87	0.40	0.37	1.08	0.69
Aug. 30	5.14	0.08	0.12	2.69[1]	1.44
Sept. 7	8.68	0.04	0.00	0.45	2.08
Sept. 20	13.87	0.36	1.05	0.98	5.41

[1] This does not indicate a trend but is the result of 3 high counts from one leaf.

In 1951 experiments were conducted with ovotran,[1] as well as with aramite. The results obtained in an extensive experiment comparing these two materials was conducted in a honeydew melon field at Woodland, Yolo County and is summarized in table 4. The treatments were applied at about 30 pounds per acre and both materials resulted in satisfactory control, with evotran being slightly more effective than aramite. Both of these acaricides were successfully used in combination with 3 per cent DDT. Therefore in cases where destructive populations of the melon leafhopper or cucumber beetles occur along with mites there is no reason why one of these dust mixtures should not be applied to control the insects as well as the mites. Mite injury in the checks was so severe that the vines dried up considerably in advance of the completion of harvest. There is no question but that the treatments saved a large proportion of the crop.

Another field in the same area was treated with a 3 per cent aramite dust applied at the rate of only 16.5 pounds to the acre. The coverage was exceptionally good and despite the light dosage the control obtained was relatively good when compared to the check. On August 28 the average number of mites was 13.7. After treatment on September 27 the checks showed 93.5 and the treated only 12.9 per sample. On October 10 the check showed 40.9 and the treated only 9.1 mites per sample. Here again as a result of a large number of mites the melon vines in the check dried up before harvest was complete.

Other experiments in which aramite and ovotran were compared were con-

[1] p-chlorophenyl-phenylchlorobenzene sulfonate.

ducted in San Joaquin and Stanislaus Counties. In general a 10 per cent ovotran dust performed better than a 3 per cent aramite dust. In two experiments, highly satisfactory control of mites was obtained with an aramite emulsion spray applied with a ground rig at the rate of one pound of aramite in 20 gallons of water per acre. The stock emulsion used contained 2 pounds of aramite to the gallon.

Natural enemies of mites are usually to be found in melon fields and on occasions they are abundant enough to control serious infestations. Even when their work is not so obvious predators probably constitute one of the important factors regulating mite abundance. Among the more important of the natural enemies are the anthocorid, *Orius tristicolor* (White); the six-spotted predacious thrips, *Scolothrips sexmaculatus* Perg.; predacious laelaptid mites and a *Stethorus* ladybird beetle.

In the early spring of 1950 the mite *Petrobia latens* (Müller) was causing considerable injury to germination stands of cantaloupes in the vicinity of Firebaugh in the central San Joaquin Valley. Portions of some fields were heavily infested with the pest. This mite has generally been considered to be a pest of grasses, although it is known to attack other crops. Reynolds & Swift (1951) reported it to be attacking cantaloupes as well as onions and carrots in the Imperial Valley of California. In the Firebaugh area the pest was controlled where necessary with applications of parathion.

SUMMARY AND CONCLUSIONS.—Applications of DDT and related insecticides when applied to melons have a tendency to result in an increase in the mite population. Because DDT is so effective against cucumber beetles and the melon leafhopper, it occupies an important place in the melon insect control program. In order to obtain the greatest value from this insecticide with the least harmful effects it is suggested that its use be largely limited to the control of the melon leafhopper. Before this pest reaches a level where control is necessary, cryolite can be used for the control of cucumber beetles which are usually the most serious pests during the early stages of growth. However, DDT is more effective against cucumber beetles than is cryolite so if severe infestations of these beetles occur and the young plants are heavily infested with thrips, light but thorough applications of DDT are justifiable. Because serious increase in the mite population is correlated with increased dosage, DDT should not be used at a rate of more than 1 pound of actual toxicant to the acre. At this dosage effective control of the melon leafhopper and cucumber beetles is assured if the equipment used gives even and thorough coverage. Halfway measures should be avoided, because they mean frequent applications which in turn are almost certain to result in serious mite infestations, and the possibility of an increase in the melon aphid population. Where DDT and related insecticidal dusts are applied to honeydew melons, they should be used in combination with at least 50 per cent sulfur. This mixture has been shown to have a depressing effect upon mites on honeydew melons. Because of burning, sulfur cannot be applied to most other varieties of melons.

Where evenly and thoroughly applied by ground rig at the rate of 20 pounds to the acre 1 per cent tetraethyl pyrophosphate dust or a 2 per cent parathion dust is effective against all stages of mites except those in the egg stage. Highly satisfactory control usually results if a second application is made within about 7 to 10 days to kill those mites that hatched from the eggs before they have had an opportunity to mate and lay eggs. Applications of tetraethyl pyrophosphate dust if applied to vines heavily wet with dew are likely to result in poor control because the tetraethyl pyrophosphate is probably hydrolyzed before it has had an opportunity to result in a good kill of the mites.

Dusts containing 3 per cent aramite or 10 per cent ovotran result in very satisfactory control of mites if they are thoroughly and evenly applied by ground dusters. These acaricides can be successfully combined with DDT if it is necessary to control cucumber beetles or the melon leafhopper along with the mite. An aramite emulsion spray applied with a ground sprayer at the rate of 1 pound of aramite in 20 gallons of water per acre resulted in satisfactory control.

Mite populations that develop late in the growth of a crop are likely to be less destructive than those which develop early. As far as the season is concerned, those populations which develop in July and August are likely to cause more dam-

age than the ones that occur in September or later.

There are a number of natural enemies of the mite which on occasions occur in sufficient numbers to control the pest.

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The Speed of Toxic Action on the Pea Aphid of Several Insecticides[1]

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The pea aphid, *Macrosiphum pisi* (Kalt.), is often a serious pest to legumes, particularly peas and beans, throughout Oregon. It transmits the viruses causing pea enation mosaic, bean yellow mosaic and alfalfa mosaic to peas, and the virus causing bean yellow mosaic to beans. During favorable years these viruses cause severe losses to these two crops and, since their spread results principally from the feeding and movement of the pea aphid, this insect is indirectly responsible for the resulting damage.

Before the advent of DDT in 1945, the control of the pea aphid was dependent upon the use of two groups of insecticides: the nicotine and the rotenone-bearing materials. Nicotine insecticides are most effective at temperatures above 70° F. It is necessary, however, to control the pea aphid early in the season when it begins to build up its population and the air temperature is low. The successful use of derris to control the pea aphid was obtained by Dudley *et al.* (1936) in Wisconsin and Gray & Schuh (1941) in Oregon. One objection to rotenone-bearing materials is their excessive cost.

Harries (1944) first reported the toxicity of DDT to the pea aphid. It has been established that even at very low dosages appreciable amounts of DDT appear in the milk and butter of lactating animals fed on pea vines bearing DDT residues. It is, therefore, not advisable to apply DDT to pea vines used for animal forage.

For satisfactory control of the pea aphid, it seems necessary to find a material which will kill the aphids fast enough to prevent further spread of virus diseases and, at the same time, leave no toxic residue harmful to man or animal. Experiments were carried out to determine the relative speed of toxic action of 15 insecticides on wingless adult pea aphids during the period of 1948 to 1950.

METHODS AND MATERIALS.—In rearing pea aphids for laboratory tests the author followed, more or less, the methods developed by Stone (1940) and modified by Dieter *et al.* (1944). Broad beans were planted in the greenhouse every two weeks so there was always a sufficient supply of young succulent plants present for rearing aphids. Only those aphids uniform in size and vigor were selected for testing.

The dusting tower constructed was similar to that described by Waters (1943). All chemicals were tested in dust form and were mixed with a mortar and pestle. Talc was used as a diluent for all the mixtures except as otherwise stated. The preliminary experiment indicated that when 0.33 gram of talc was dusted with the dust gun in the settling tower and the dust was allowed to settle for exactly one minute, a very even dust deposit was obtained. The weight of the dust deposits on four 1 by 3 inch glass slides averages 0.0094 grams. The variation in the dust deposits on different slides was slight. The deposit of 0.0094 grams per 3 square inches corresponds to 43 pounds per acre.

By means of continuous observations the exact reaction time of each individual in each test was recorded. These observa-

[1] This paper is part of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science.

[2] The author, a graduate student from China, is indebted to Dr. H. H. Crowell under whose direction this work was done, for his assistance and suggestions.

Table 1.—The speed of toxic action of different chemicals to pea aphids.

CHEMICALS	DUST CONC.	NOS. OF APHIDS USED	TEMP. °F.	TIME REQUIRED TO KILL 50% Hours	50% Min.	98% Hours	98% Min.
Talc	—	68	67–72	13	28	23	51
Toxaphene	5%	33	72	13	20	19	+
Chlordan	5%	28	72	9	24	18	8
EPN	0.86%	72	74	5	26	8	6
Dieldrin	1%	37	75	4	7	6	43
Aldrin	1%	35	75	3	44	7	32
TM-1[1]	—	37	69	2	41	8	47
TDE	5%	110	72	2	34	4	35
Methoxychlor	10%	72	75	2	1	5	34
Parathion	1%	70	70	1	8	1	43
	2%	72	70	1	21	1	53
DDT mixture	5%	72	72	0	57	1	45
5% DDT & 10% Sulfur[2]		70	72	0	44	1	14
Gamma BHC	1%	71	72	0	56	1	54
Rotenone mixture[3]	5%	72	72	0	47	1	23
TM-2[4]	—	74	74	0	40	1	28
TEPP	0.18%	67	74	0	20	0	56
Nicotine	1%	71	78	0	15	1	12
	3%	73	72	0	12	0	50

[1] Test material 1, S. B. Penick and Co. The dust concentrate was cut to one-fifth its strength and has the following ingredients:

Di-N-Propyl maleate isosafrole conc.	0.50%	Pyrethrins	0.05%
Rotenone	0.25%	Total inert ingredients	99.20%

[2] Consists of 5% DDT and 10% sulfur and blended by mixing in the dust state.
[3] This consists of 5% rotenone, 10% other ethyl ether extractives of cube and 85% inert ingredients.
[4] This consists of the following ingredients:

Tech. Piperonyl cyclonene	0.50%	Other cubé resins	0.50%
Rotenone	0.25%	Sulfur (93% through 325 mesh)	25.00%
Pyrethrins	0.05%	Inert ingredients	73.00%

tions were started before the first individual responded and continued until the reactions stopped. A few tests lasted for 24 hours due to the slowness of the toxic action of certain chemicals. In such cases it was necessary to use a small preliminary test series to determine the range of time from when the first individual responded to the time when the reactions stopped. With this guidance the main series of observations could be planned conveniently. Although conventional ranges of dust concentrations were used in most cases, the concentrations of some of the test materials had to be adjusted in order to get adequate data which could be subjected to statistical analysis. Preliminary tests indicated that pea aphids could live away from host plants for 20 hours before showing any mortality under laboratory conditions. It was thus possible to keep the dusted aphids under continuous observation in petri dishes without having to return them to their host plants for nourishment. Individual survival time was recorded starting from the time when the dust first discharged into the cylinder. The aphids showed different symptoms of reaction to different chemicals. They were considered dead when they no longer were

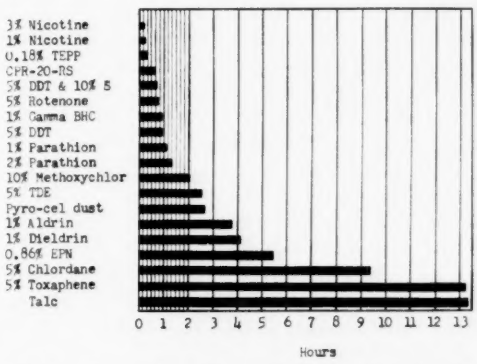

FIG. 1.—Comparison of the speed of toxic action of chemicals to the pea aphid at 50% mortality level.

able to stand on their legs, or maintain their normal posture. Sometimes the dusted aphids stumbled several times but their survival times were not taken until the end point was definitely attained.

The method used in obtaining the time-mortality curves was that of Bliss (1937). When the per cent mortality was transformed to probits and the time units were transformed to logarithms or to reciprocals (rates) or the original units, normal distributions were obtained in most cases. Only those functions of time which gave

normal distributions were used for calculating the time required to kill 50 per cent and 98 per cent respectively.

RESULTS AND DISCUSSION.—The speed of toxic action of the different chemicals as determined in these tests is shown in table 1 and figure 1.

The tested insecticides may be divided into two groups, according to the symptoms of poisoning which they produce: those insecticides which produce definite signs of excitement and hyperactivity immediately after the application of the dust, and those which produced an anesthetizing effect. Nicotine is a typical example of the first group and also belonging to this category are benzene hexachloride, parathion, and TEPP. In the second group rotenone is a typical example. Also belonging to the second category are "CPR-20-RS," "Pyro-cel," DDT, methoxychlor, TDE, chlordan, toxaphene, aldrin, dieldrin and EPN. The insecticides in the first group in most cases are also faster in their killing action. The speed of toxic action and the ability to induce hyperexcitability are, however, two different and independent characteristics of an insecticide. For example, five per cent DDT required only 57 minutes to kill 50 per cent of the treated aphids, while 68 minutes were needed for one per cent parathion to kill the same percentage, although parathion induces hyperexcitability. The lack of ability of an insecticide to induce hyperexcitability therefore, does not necessarily imply slowness of killing action.

DDT, methoxychlor and TDE are closely related insecticides, but methocychlor and TDE are much slower in their toxic action than DDT. A similar situation was found with the organic phosphates. TEPP killed aphids many times faster than parathion and EPN. Closely related chemicals, do not necessarily follow this pattern of toxic action on the pea aphid according to these tests.

The pea aphid is one of the few aphids which are highly susceptible to DDT poisoning. It is interesting to note that this insect is not nearly as susceptible to chlordan, aldrin, and dieldrin, which are many times more toxic than DDT to insects in general. The results of tests with methoxychlor are erratic.

The results indicated that 1 per cent and 3 per cent nicotine dusts required only 15 and 12 minutes, respectively, to reach the 50 per cent mortality level. Under favorable temperature conditions nicotine seems to be a dependable insecticide for the control of pea aphids. Tetraethyl pyrophosphate is the most rapid acting of the organic phosphates tested on the pea aphid. Since tetraethyl pyrophosphate breaks down rapidly in the presence of moisture, no residue problem exists when this insecticide is employed.

None of the tested insecticides seemed to inhibit the reproduction of the agamic adult aphids. Many aphids, not killed within one hour by the insecticides, were able to produce one or more offspring.

SUMMARY.—A total of 23 laboratory insecticidal tests were carried out on different dates on pea aphids and the results of 19 tests are presented in this paper. The insecticides which induced hyperexcitability in aphids, in most cases, were also faster in their killing action. The lack of this property, however, did not necessarily imply slowness of killing action. TEPP killed aphids much faster than parathion and EPN. Toxaphene, chlordan, dieldrin and aldrin gave very poor test results. The speed of toxic action of toxaphene is about equal to that of pure talc.

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Control of Mites on Woody Ornamental Plants

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In recent years mites have become more troublesome in Ohio on woody ornamentals, particularly arborvitae, spruce and juniper. This increase in abundance is apparently correlated with an increase in the use of DDT for the control of other pests (Schread 1951). A number of new acaricides that have recently become available have been used extensively in control of the European red mite and the two-spotted spider mite. Inasmuch as mite species vary greatly in their susceptibility to the action of acaricides the writer became interested in testing some of the new materials in control of mites on woody ornamental plants with particular emphasis on the spruce mite, *Paratetranychus ununguis* Jacobi.

A paper by Neiswander & Rodriguez (1947) entitled "Control of the spruce mite" reported excellent results with each of five materials used in summer sprays. Two of these were experimental materials that have not been produced commercially and two others that were used in 1947 are no longer available.

In 1949 the writer together with J. G. Rodriguez tested a number of acaricides, using 20 treatments in one series and 15 in another. In these tests, p-chlorophenyl p-chlorobenzene sulfonate[1] proved very effective and remained effective longer than other materials tested. Chloroethyl butylphenoxy methyl ethyl sulfite,[2] 2,4-dichlorophenyl ester benzene sulfonic acid,[3] di (p-chlorophenyl) methyl carbinol,[4] and a commercial rotenone preparation all proved more effective than the organic phosphates, parathion, tetraethyl pyrophosphate, and EPN (ethyl p-nitrophenyl thionobenzenephosphonate).

Spruce Mite on Juniper.—Experiments in control of the spruce mite were again carried on in 1951. The first treatments were applied to single plant plots on August 3 in a nursery in Lake County. All treatments were replicated five times. Sprays were applied with a knapsack sprayer and dusts with a rotary hand duster. The plants used in the experimental work were upright junipers, primarily *Juniperus virginiana canaerti*, approximately 3 feet in height. The work was begun too late for best results because the plants were already discolored as a result of mite injury.

Treatments were evaluated first by counting living and dead mites on five twigs each about 5 inches long taken at random from each plant. In later records only living mites were counted from similar samples. The data obtained are summarized in table 1.

Although a number of the materials were used at relatively low concentrations, all proved effective. It seems probable that any of the treatments listed would prove satisfactory if used in two applications with an interval of approximately 5 days. However, p-chlorophenyl p-chlorobenzene sulfonate, a trialkyl thiophosphate,[5] and 0,0-dimethyl 0-p-nitrophenyl thiophosphate[6] appeared somewhat more effective than the remaining materials tested.

In no case did the population build up appreciably during the period in which this series of experiments was under way. Observations indicate that this is not unusual for the spruce mite. Populations have been observed to build-up rapidly in May and June, remain relatively unchanged or possibly subside in midsummer, and build-up again in September and October. In this respect the spruce mite differs from the European red mite and the two-spotted spider mite which frequently are most troublesome during the hot summer months.

Although the air was relatively quiet when the treatments were applied, it was evident that some drift of sprays and dusts occurred, or at least that certain treatments affected the mite populations on adjacent trees. This was shown by the fact that most mites were killed on an occasional untreated tree that was surrounded by treated plants.

The dust treatments listed in table 1 were used again in the same planting on August 10, but were not replicated.

[1] Ovotran, Dow Chemical Company.
[2] Aramite, U. S. Rubber Company.
[3] General Chemical Div., Allied Chemical & Dye Corp. (Compound 923).
[4] *Dimite*, Sherwin-Williams Company.
[5] Systox, Geary Chemical Company.
[6] Metacide, Dow Chemical Company. (This material also contains 6.2 per cent parathion and 2.7 per cent related organic phosphates).

Table 1.—Spruce mite mortality following treatments applied August 3, 1951.

Material Used	August 8		Mean No. Alive	
	Mean No. Mites	Per Cent Dead	Aug. 15	Aug. 28
(1) *Sprays*—quantity in 100 gallons				
P-chlorophenyl p-chlorobenzene sulfonate 50% WP, 1 pound	67.0	97.9	2.0	.2
Compound 4049[1] (S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate) 25% WP, 1 pound	111.8	97.3	7.8	2.4
EPN 25% WP, 4 oz.	87.8	92.3	6.8	3.6
Parathion 15% WP, 8 oz.	83.8	90.2	8.2	2.8
Compound 923 25% WP, 1 pound	65.6	84.8	7.6	6.8
Chloroethyl butylphenoxy methyl ethyl sulfite 15% WP, 1 pound	52.4	90.1	12.2	4.8
A trialkyl thiophosphate 32.1% emulsion, 1 pint	74.8	96.0	0	0
0,0-dimethyl 0-p-nitrophenyl thiophosphate 24.5% emulsion, 1 pint	57.0	96.5	1.0	1.2
(2) *Dusts*				
Compound 4049,[1] 5%	75.6	97.4	5.4	1.0
Compound 923, 10%	70.0	94.8	11.0	5.0
Chloroethyl butylphenoxy methyl ethyl sulfite, 5%	70.6	87.5	5.6	4.8
P-chlorophenyl p-chlorobenzene sulfonate, 5%	76.2	97.4	1.2	1.4
Check (No treatment)	96.8	6.4	—	—

[1] American Cyanamid Company.

Plots were seven rows wide and contained approximately 70 plants. Population counts were made three times as shown in table 2.

The spray materials listed in table 1 were used again on August 15, but in several cases the concentrations were increased. Treatments were again replicated five times on one-plant plots, but all plots were located in a single row in order to avoid much of the contamination caused by spray drift. Population counts were made at two different times as shown in table 3.

Data shown in table 2, that were taken 1 and 4 weeks after the dusts were applied, correspond in a general way with those shown in table 1. However, a third count made 7 weeks after the dusts were applied showed greater differences. The fall population built up greatly on all plants except those dusted with p-chlorophenyl p-chlorobenzene sulfonate. The number of living mites found on plants in plots treated with this material was only 3 per cent as large as the number found on plants in the plots that were most heavily infested. This corresponds with results obtained in 1949 when p-chlorophenyl p-chlorobenzene sulfonate demonstrated unusually long-lasting qualities.

P-chlorophenyl p-chlorobenzene sulfonate and a trialkyl thiophosphate appear outstanding in table 3. An analysis of variance shows that, at the 5 per cent level, both were significantly different from parathion.

SPRUCE MITE ON NORWAY SPRUCE.—During September a spruce mite population was found to be developing in a planting of Norway spruce, *Picea abies* (L.), trees approximately three feet in height on the Experiment Station grounds. Three experimental sprays were applied in this block on September 17, 1951. One plant was again used as a plot unit and each treatment was replicated five times.

Table 2.—Spruce mite populations following dust treatments applied August 10.

Materials Used	Mean No. Living Mites per 5 Twig Sample		
	Aug. 15	Sept. 6	Sept. 28
Compound 4049 5% dust	3.6	18.2	174.0
Compound 923 10% dust	13.2	31.2	209.6
Chloroethyl butylphenoxy methyl ethyl sulfite 5% dust	16.8	19.0	216.3
P-chlorophenyl p-chlorobenzene sulfonate 5% dust	4.6	3.0	6.3

Table 3.—Spruce mite populations following spray treatments applied August 15, 1951.

Materials Used in 100 Gallons	Mean Living Mites per 5 Twig Sample	
	Aug. 28	Sept. 6
P-chlorophenyl p-chlorobenzene sulfonate 50% WP, 2 pounds	0	.2
Compound 4049 25% WP, 2 pounds	5.2	2.8
EPN 25% WP, 8 oz.	6.4	7.0
Parathion 15% WP, 1 pound	15.4	13.8
Compound 923 25% WP, 2 pounds	4.2	3.8
Chloroethyl butylphenoxy methyl ethyl sulfite 15% WP, 2 pounds	7.8	3.6
A trialkyl thiophosphate 31.2% emulsion, 1 pint	.2	0
0,0-dimethyl 0-p-nitrophenyl thiophosphate 24.5% emulsion, 1 pint	12.0	9.8

Treated plants were distributed largely at random, but were selected in such a way that trees adjacent to either treated or check plants were not treated. This was done in order to avoid contamination caused by spray drift. A knapsack sprayer containing a pressure gauge was employed and sprays were applied at a pressure of approximately 40 pounds.

Control data were taken 2, 10, and 29 days after the sprays were applied as shown in table 4. In the data obtained on September 19 both living and dead mites were counted in order to establish the average per cent mortality. On September 27 and October 16, however, five twigs each about 5 inches long, were examined from each plant in order to compare populations of living mites. The totals only are shown in table 4.

It will be observed that p-chlorophenyl p-chlorobenzene sulfonate again yielded excellent results. Although only 62.4 per cent of the mites were dead after 2 days, only one living mite was found on 25 twigs after 29 days had elapsed.

Compound 4049 at 3 pounds per 100 gallons demonstrated much longer lasting qualities than when used at the weaker strengths. No significant differences were evident among the three treatments on September 27, but an analysis of variance in the data obtained on October 16 shows that both p-chlorophenyl p-chlorobenzene sulfonate and Compound 4049 were significantly better, at the 1 per cent level, than Compound 923 and the check. This difference is apparently due to longer residual action.

AIRPLANE DUSTING EXPERIMENT IN CONTROL OF THE SPRUCE MITE.—Approximately 46 acres in a nursery near Springfield, Ohio were dusted by airplane for the control of the spruce mite on May 22, 1951. The dust was prepared by mixing 1 part 50 per cent p-chlorophenyl p-chlorobenzene sulfonate, 1 part talc, 1 part gypsum, and 2 parts sulfur to make a 10 per cent p-chlorophenyl p-chlorobenzene sulfonate dust. It was applied at the rate of 30 to 35 pounds per acre by an aviator. The entire cost of the operation, including the materials and the application, amounted to approximately $10.00 per acre.

Several types of plants were being grown in the dusted area, but the predominating species were arborvitae, spruce, juniper, and yew. Spruce mites were most abundant on two blocks of arborvitae in which the plants were approximately 4 feet high. Mite mortality and population records were obtained from twig samples collected in these two blocks on May 24, May 31, and June 20. In each case a one twig sample about 4 inches long was taken from each of 100 plants selected at random.

A total of 37 living and 588 dead mites was recorded on the twigs collected on May 24, indicating an original population of 6.25 mites per twig and a mortality of 94.1 per cent 2 days after the dust was applied. The 100 twigs collected on May 31 yielded 9 living spruce mites, and none were found on the twigs collected on

Table 4.—Experiments in control of spruce mite on Norway spruce. Treatments applied September 17, 1951 at Wooster, Ohio.

Materials Used in 100 Gallons	September 19		Average Number Alive on 5 Twig Sample	
	Avg. No. Mites Examined	Per Cent Dead	Sept. 27	Oct. 16
P-chlorophenyl p-chlorobenzene sulfonate 50% WP, 2 pounds	53.2	62.4	2.6	.2
Compound 923 25% WP, 3 pounds	42.2	87.2	3.0	53.8
Compound 4049 25% WP, 3 pounds	69.2	98.6	2.4	.8
Check (No treatment)	42.8	27.1	56.4	51.6

June 20, approximately one month after treatment.

A smaller number of twigs were also examined at two later dates. On July 19 no living spruce mites were found on 15 twig samples, and on October 17, 147 days after the dust was applied, three living mites were found on 40 similar twigs from the same blocks of arborvitae plants. On the latter date, however, a spruce mite infestation was observed in a block of juniper plants, *Juniperus chinensis pfitzeriana* Spaeth, that were included in the dusted area. Twenty twigs of approximately the same size taken at random from this block yielded a total of 64 mites or an average of 3.2 per twig.

In this experiment no mite injury was evident on arborvitae throughout the season following one application of p-chlorophenyl p-chlorobenzene sulfonate dust made on May 22. On juniper no damage was detected until October and at that time mite injury was visible on only an occasional plant.

MITES ON AZALEA.—Rather severe mite injury occurred on azalea plants in a nursery in Lake County, Ohio during 1951. The plants were approximately 12 inches high and were growing in nursery beds 4 feet wide and approximately 100 feet long. Many of the growing tips were deformed and stunted, and older leaves were discolored.

Two mite species were found to be present in considerable numbers and apparently both were causing damage. The larger of the two species was identified by the author as the cyclamen mite, *Tarsonemus pallidus* Banks. The other was identified by H. H. Keifer, Systematic Entomologist of the California Department of Agriculture, as *Vasates atlantazaleae* (K.) Keifer stated that the species had not been reported from Ohio previously. This tiny mite sometimes occurred in great numbers. As many as 1000 individuals were counted on the small leaves of a single growing tip.

The acaricide dusts listed in table 3 were used in small scale experiments in control of the two species on August 10. Each dust was applied in three replications on plots 4 feet wide and 9 feet long. The treatments were evaluated by dissecting samples of growing tips taken at random from each plot.

One week after the dusts were applied no cyclamen mites were found on samples from plants that had been dusted with Compound 923, whereas from 17 to 34 were found on a like number of samples from plants that received other treatments. Counts made three weeks later also showed the smallest number of mites on plants that had received Compound 923.

Vasates atlantazaleae, on the other hand, was found in numbers in all plots on August 17 except those dusted with Compound 4049. This is more significant in view of the fact that the same material proved very effective both as a dust and a spray in control of a related species, *V. destructor*, on tomato.

It seems probable in view of these results that a combination of materials will be needed for the control of the two mite species on azalea.

SUMMARY.—A number of the new acaricides were found to kill a high percentage of the spruce mites on juniper, spruce, and arborvitae.

P-chlorophenyl p-chlorobenzene sulfonate demonstrated unusually long-lasting qualities. A 10-per cent dust applied by airplane during May prevented damage throughout the summer. A trialkyl thiophosphate and Compound 4049 also appeared unusually effective.

The cyclamen mite caused damage on azalea during 1951, as did *Vasates atlantazaleae*, a species not recorded previously in Ohio. Of four acaricides tested in control of these mites, only Compound 923 proved effective in control of the cyclamen mite and only Compound 4049 in control of *V. atlantazaleae*.

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Control of Several Tree and Shrub Leaf Miners

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Development of the newer chlorinated hydrocarbon and phosphorous ester type insecticides has opened up new possibilities for control of leaf miners on ornamental plants, as well as on food crops. In the past, leaf miner control methods have been none too satisfactory. Treatments were directed mainly against adults. Nicotine had been widely used, but was quickly replaced by DDT, mainly because of the longer residual action of DDT. Even with DDT application timing is critical and difficult, and two treatments are necessary against miners with a long adult flight period. Mite increase following DDT application has been a serious problem.

The concept of killing larval miners within plant tissues is not new. Nicotine and selenium compounds were long ago shown to be effective against certain miners (Herrick 1912; O'Kane & Weigel 1921). Benzene hexachloride, chlordane, and toxaphene, shortly after their inception as insecticides, were found to be effective against certain leaf miners in crop plants. Considering these possibilities, investigations were initiated in 1948 on control of leaf miners through kill within the leaves, and comparison to adult control measures.

Methods and Materials.—Nursery and permanent plantings of birch (*Betula pendula* Roth, *B. populifolia* Marsh), elm, (*Ulmus glabra* Huds., *U. procera* Salisb.), American holly (*Ilex opaca* Ait.), boxwood (*Buxus sempervirens* L., *B. microphylla* Sieb. and Zucc.) and arbor vitae (*Thuja occidentalis* L., *T. orientalis* L.) were sprayed using mainly a 50-gallon tank, 4 horsepower, 7 gallon per minute sprayer. A three-nozzle broom was used in most of the work, except on taller elms in which case a spray gun was used. Pressure was maintained at 350 pounds per square inch. No figures on volume used are given as this depended on size, denseness, planting, tree species, etc., but sufficient spray was applied to give complete coverage and some run-off. Locally available commercial wettable powders and emulsifiable solutions were used as indicated in the tables. Technical chlordane was first mixed with oil then emulsified in the spray tank for one treatment on birch and boxwood. Technical chlordane was mixed with kerosene and applied by a mist blower in one treatment on elm.

Counts were made at intervals after spraying by laboratory examination and dissection of clippings. The rapidly developing miners such as birch leaf miner and elm leaf miner required counts less than one week after spraying; and slowly developing miners such as holly leaf miner, boxwood leaf miner, and arbor vitae leaf miner required counts a month or more after treatment. Wherever possible mortality counts and infestation counts (living per leaf or per sprig) were taken at several intervals following treatment.

All the birch, holly, and boxwood work and the initial arbor vitae work was done in Nassau and Suffolk counties, Long Island, N. Y. The elm work and the 1951 arbor vitae work was done in Ithaca, N. Y. Each table represents work done at several plot locations, so that similar dates do not necessarily indicate the same insect or plant development as there is great local and yearly variation particularly on Long Island.

Results and Discussion.—1. Birch Leaf Miner, *Fenusa pusilla* (Klug). Nicotine spray directed against adult sawflies and eggs has been the standard treatment (Friend 1933). Good control may be obtained but timing is critical and difficult, and several applications are necessary. The authors have done no work with DDT or other insecticides against adults as unpublished communications indicated little promise. Larval treatments appeared much more promising as first generation mines first appear as small brown spots on well expanded leaves, giving a good spray timing indicator.

Table 1 indicates results obtained during 1948 and 1949. The May treatments were applied against small first generation larvae and some eggs in spring leaves, whereas the July and August treatments were applied against overlapping summer generations in all instars and eggs in summer tip and sucker growth. Chlor-

dane produced consistently higher kills at the concentrations tested than did aldrin or parathion. Chlordane suspensions were superior to emulsions. No reason is known for the higher kills produced by the suspensions, but it is suspected that poor emulsification of this early viscous 74% chlordane concentrate may have reduced its effectiveness. Addition of emulsifiable summer oil to chlordane and parathion did not increase kills sufficiently to warrant further testing. Since 0.5 lb. actual aldrin in 100 gallons appeared inferior to 1 lb. actual chlordane, it was considered that aldrin showed no practical promise and was dropped from further consideration. In all cases it was noted that first instar miners were more susceptible to the treatments than larger mines. Contrary to these data, Kerr (1951) found aldrin to be superior to chlordane; the data being expressed in terms of population rather than mortality.

Table 2 indicates results obtained in 1950. Considerable difficulty was encountered in timing applications during 1950. Late May was unusually wet and cold so that oviposition, hatching, and larval growth were delayed. The May 17 treatments were timed by noting the first brown mine spots, but apparently the residual actions were too short to control the later first generation miners. May 26 treatments were more successful, although there was considerable mining. The higher concentration of parathion gave good kills, but chlordane performed equally well, so that parathion was dropped from further consideration on account of mammalian toxicity. DDT was ineffective, and nicotine very inferior in kill. The June treatments were applied against all instars of second generation miners. The relative resistance of the larger miners resulted in lowered kills, with benzene hexachloride and chlordane approximately equal at the concentrations used. Schradan appeared very promising. Kerr (1951), contrary to these data, found nicotine to be superior to chlordane.

Table 3 indicates results in 1951. Warm sunny weather in mid May forced rapid oviposition, hatch, and larval growth. Control was excellent with Systox, lindane, and the higher concentrations of chlordane. In all cases with these materials, sprays applied against first generation eggs and larvae killed all larvae present, and all larvae hatching within 7 days of treatment. One pound actual chlordane and 2 lbs. actual toxaphene per 100 gallons of water were slightly inferior. Nicotine at 1 pint was very inferior. Schradan, contrary to 1950 results, was almost completely ineffective. The sample used had been stored for a year and had possibly decomposed although storage conditions were good.

Systox appeared to give the longest residual action as evidenced by complete protection 16 days after treatment. Lindane was erratic, in one case considerable numbers of late first generation miners survived, evidencing poorer residual action than chlordane or Systox. The single treatments did not protect against second or later generation miners. The first generation mined leaves to a large extent fell from the trees in June, so that the trees receiving the best treatments appeared only slightly superior to check and other trees in midsummer. Undoubtedly treatments against at least the first and second generation larvae would be necessary to produce satisfactory seasonal control. For this purpose lindane is considered the most desirable material from the standpoints of cost, safety, visible residue and insect complex. Aphids are often serious on birch, and lindane has been noted to aid in their control. Hamilton (1951) considers lindane or BHC sprays or mists very effective controls for birch leaf miner.

No plant injury was noted in any of the treatments. Birch was heavily sprayed with 10 lbs. of 40 per cent chlordane wettable powder in 100 gallons of water and no injury resulted. The mines containing killed larvae from all treatments produced hardened brown spots on the leaves, and leaf blade areas beyond these spots appeared off color and roughened. However, there is little if any detraction from the appearance of the tree. Commercial arborists and nurserymen have used chlordane or lindane, two treatments, with excellent control and good customer satisfaction with the tree appearance.

2. ELM LEAF MINER.—*Fenusa ulmi* Sund. The elm leaf miner is very similar to the birch leaf miner in insecticide susceptibility, and the same general control practices have obtained in the

past, along with similar difficulties. Herrick (1912) found nicotine effective against larval miners. Some initial experimental work was done in 1950 indicating parathion and chlordane to be effective against larvae within the leaves.

Table 4 indicates results achieved in 1951. Chlordane, lindane, and Systox were all highly effective when applied as sprays. Nicotine was comparatively ineffective. Addition of extra spreader did not increase the effectiveness of the chlordane suspension spray. Throughout the tests on all species of leaf miners it was noted that extra spreader, added to the commercial insecticide formulations, gave no increased effectiveness. Probably improved spreading was offset by higher run-off. The mist concentrate application of chlordane was ineffective, probably due to incomplete coverage, as volume was low for fear of plant injury. No leaf injury or leaf drop was noted in any of the treatments even though these elm species are known to be susceptible to DDT injury. Contrary to birch leaf miner, the single first generation treatments gave good seasonal control, resulting in excellent tree appearance. Again lindane is considered the most practical insecticide considering all factors affecting use on ornamental elms.

3. HOLLY LEAF MINER.—*Phytomyza ilicis* (Curt.). Nicotine sulfate and DDT wettable powder have been commonly used to control holly leaf miner through kill of the adult flies (Hartzell *et al.*, 1943; Kerr 1950). The adults are present for about a month so that several treatments are necessary for complete control. Table 5 gives March 1949 holly leaf miner infestation counts of plants treated in May 1948. Good but incomplete protection resulted from the single treatment of 1.5 lbs. actual DDT per 100 gallons of water. Probably the extra wetter reduced the deposit from the 1 lb. actual DDT spray, so that insufficient residual effect resulted in poor control. Southern red mite, *Paratetranychus ilicis* (Mc.G), was abundant in the DDT plots, and observations of commercially DDT sprayed or dusted holly often showed heavy mite populations. It is considered that mite build-up on holly following DDT treatment is a definite drawback to adult type control.

Table 6 indicates results of 1950 and 1951 holly treatments applied against small larvae inside the leaves. Systox and chlordane emulsion gave a slight population reduction, but none of the materials used evidenced any promise. Kerr (1951) also found chlordane to be ineffective, but found aldrin and dieldrin to be effective. Underhill (1943) tested a number of contact sprays against larval and pupal miners, including nicotine, dinitros, and organic thiocyanates but none was effective.

4. BOXWOOD LEAF MINER.—*Monarthropalpus buxi* (Laboulb.) Boxwood leaf miner had been considered a very difficult pest to control until the advent of DDT. Nicotine and molasses in repeated applications, with the help of fair weather, was effective (Hamilton 1925). A single correctly timed application of DDT gives good control as the adult fly usually is present for less than two weeks (Pyenson 1946).

Table 7 indicates results of DDT treatments timed by the appearance of black color in the pupal appendages in 1948 and 1949. The May 28 treatments gave only fair control as cool wet weather delayed adult emergence, and the excess spreader probably caused excessive runoff (boxwood new foliage is extremely hard to wet). The May 23 and 27 treatments at different locations were timed well and gave good control. Boxwood mite, *Neotetranychus buxi* Garm., injury increased following DDT treatment, and is a definite drawback to DDT adult control.

Table 8 indicates comparisons of treatments against adults, eggs, and larvae during 1949 and 1950. Parathion gave complete control of larvae in all but one plot. Apparently parathion is effective at any time during June and July after hatch is complete. A lengthy search by two men discovered no live miners in the parathion plots the following April and May. At 0.15 lb. parathion per 100 gallons of water, incomplete coverage resulted in incomplete control. Parathion and DDT combined applied May 19 at the end of the adult flight was ineffective against eggs and had insufficient residual action to kill hatching larvae. A heavy application (3 lbs. per 100 gallons of water) of chlordane gave incomplete control. Further work with chlordane should be done. Schradan and benzene hexachloride gave poor control.

Table 1.—Birch leaf miner initial experiments.

Formulation in 100 Gallons of Water	Date Sprayed	Per Cent Killed[1]	Live per 100 Mined Leaves[2]
1.35 lbs. 74% Chlordane Emul.	May 18	61.7	138
1.35 lbs. 74% Chlordane Emul.	Aug. 25	62.2	104
1 lb. Tech. Chlordane, 2 qts. oil	July 16	88.7	20
2.7 lbs. 74% Chlordane Emul.	May 18	75.1	150
2.5 lbs. 40% Chlordane W.P.	Aug. 25	88.1	18
4 lbs. 50% Chlordane W.P.	May 17	92.8	40
0.5 lbs. 25% Aldrin W.P.	May 18	24.2	331
2 lbs. 25% Aldrin W.P.	May 18	59.7	200
1 lb. 25% Parathion W.P.	July 16	66.0	57
1 lb. 25% Parathion W.P.	July 19	54.0	130
2 lbs. 25% Parathion W.P.	Aug. 25	59.9	111
2 lbs. 25% Parathion W.P., 2 qts. oil	Aug. 25	65.3	113
Average of Untreated	—	—	323[3]

[1] Corrected for varying mortality in checks, which averaged 7.5% mortality.
[2] Only infested leaves picked for mortality and population counts.
[3] Actual counts of check live per 100 leaves were: May 17—575; May 18—425; July 16—167; July 19—267; Aug. 25—188.

Table 2.—Birch leaf miner 1950 experiments.

Formulation in 100 Gallons of Water	Date Sprayed	Per Cent Killed[1]	Live in 100 Mined Leaves[2]
5 lbs. 40% Chlordane W.P.	May 17	45.8	150
5 lbs. 40% Chlordane W.P.	May 26	82.6	42
5 lbs. 40% Chlordane W.P.	June 9	62.9	97
1 pint 63.3% Schradan	June 9	91.0	33
2 lbs. 12% Gamma BHC W.P.	June 9	67.5	93
6 lbs. 25% Toxaphene W.P.	June 9	9.9	139
1 lb. 25% Parathion W.P.	May 17	6.9	470
2 lbs. 15% Parathion W.P.	May 26	81.6	71
1 pint 40% Nicotine Sulfate, 5 lbs. Soap	May 17	32.5	230
1 qt. 40% Nicotine Sulfate, 4 lbs. Soap	May 26	50.1	129
1 qt. 25% DDT Emul.	May 17	0	470
1 qt. 25% DDT Emul.	May 26	0	342
Untreated	(May 17)	—	410
Untreated	(May 26)	—	204
Untreated	(June 9)	—	134

[1] Corrected for varying mortality in checks, which averaged 8.6% mortality.
[2] Only infested leaves picked for mortality and population counts.

The level of effectiveness of a properly timed DDT treatment against adults is included for comparison.

5. ARBOR-VITAE LEAF MINER.—*Argyresthia thuiella* (Pack). Nicotine sulfate spray has been used to kill adults, eggs, and external larvae of arbor-vitae leaf miners. (Felt 1915; Brower 1935). Since the adults are in flight for as long as a month, repeated applications are necessary. Treatments against external larvae have been successful but require exact timing. Control is complicated by the presence of at least three species of leaf miners (*Argyresthia thuiella*, *A. freyella*, and *Recurvaria thujaella*) differing in adult flight periods. DDT has been found to be very effective against adults but the long flight period required more than one treatment for complete control

Table 3.—Birch leaf miner 1951 experiments.

Formulation in 100 Gallons of Water	Date Sprayed	Killed[1]	7 Days		16 Days	2 Months
			Per Cent of Leaves Mined	Live per 100 Leaves[2]	Per Cent of Leaves Mined	Per Cent of Leaves Mined
1 pint 50% Systox Emul.	May 8	100	0	0	0	—
1 pint 50% Systox Emul.	May 15	100	0	0	0	18.7
0.5 pint 50% Systox Emul.	May 16	100	0	0	0.4	6.6
1 lb. 25% Lindane W.P.	May 15	100	0	0	17.6	14.8
1 lb. 25% Lindane W.P.	May 16	100	0	0	0.6	—
10 lbs. 40% Chlordane W.P.	May 16	100	0	0	1.5	14.8
5 lbs. 40% Chlordane W.P.	May 8	100	0	0	1.2	—
5 lbs. 40% Chlordane W.P.	May 15	100	0	0	1.0	19.2
5 lbs. 40% Chlordane W.P.	May 16	100	0	0	1.1	13.0
2.5 lbs. 40% Chlordane W.P.	May 16	94.1	1.0	1.6	8.2	19.3
5 lbs. 40% Chlordane W.P., 1 pint 40% Nicotine sulfate	May 8	100	0	0	0	—
1 pint 40% Nicotine Sulfate, 3 lbs. Soap	May 8	67.4	17.7	13.8	5.3	—
0.1 pint 63.3% Octamethyl Pyrophosphoramide	May 8	6.3	24.5	35.3	21.0	—
0.5 pint 63.3% Octamethyl Pyrophosphoramide	May 8	8.3	22.4	71.4	46.4	—
8 lbs. 25% Toxaphene W.P.	May 15	92.	3.9	6.3	31.4	22.6
8 lbs. 25% Toxaphene W.P.	May 16	—	0.4	0.2	1.3	6.8
Untreated	(May 8)	—	17.0	44.1	64.9	—
Untreated	(May 15)	—	67.0	210.9	58.2	36.2
Untreated	(May 16)	—	7.1	27.0	48.6	26.7

[1] Corrected for varying mortality in the checks, which averaged 2.6% mortality.
[2] Average of 100 leaves on each of 5 branches counted, live per 100 leaves includes many unmined leaves.

Table 4.—Elm leaf miner 1951 experiments.

Formulation in 100 Gallons of Water	Date Sprayed	Per Cent Mortality	Live in 100 Leaves
4 lbs. 40% Chlordane W.P.	May 22	100.0	0
4 lbs. 40% Chlordane W.P., 1.5 oz. Spreader[1]	May 22	96.6	17
4 lbs. 40% Chlordane W.P., 2 lbs. 15% Parathion W.P.	May 22	98.6	5
1 pint 50% Systox Emul.	June 6	99.6	2
1 lb. 25% Lindane W.P.	June 6	99.2	4
1 pint 40% Nicotine Sulfate, 2 lbs. Soap	May 22	55.8	445
Chlordane Mist Concentrate[2]	May 22	28.1	575
Untreated	(May 22)	7.0	970
Untreated	(June 6)	15.4[3]	468

[1] Grasseli Spreader-Sticker.
[2] 5% Chlordane solution in kerosene applied by mist blower.
[3] Spray drift from the Systox plot probably caused some check mortality, no corrections calculated in treated plot per cent mortalities.

Table 5.—Holly leaf miner May 28 treatments against adults.

Formulation in 100 Gallons of Water	Per Cent of Leaves Mined
3 lbs. 50% DDT W.P.	7.3
2 lbs. 50% DDT W.P. 3.5 oz. Triton X 100	34.0
Untreated	36.7

Table 6.—Holly leaf miner.

Formulation in 100 Gallons of Water	Date Sprayed	Per Cent Killed[1]	Live in 100 Mines
2 lbs. 50% Chlordane W.P.	Aug. 30	12.2	54.3
1.35 lbs. 74% Chlordane Emul.	Aug. 30	21.4	33.9
5 lbs. 40% Chlordane W.P.	July 31	0.9	53.3
1 lb. 15% Parathion W.P.	July 31	0	79.3
1.8 qts. 50% Toxaphene Emul.[2]	July 31	4.9	67.0
1 pint 40% Nicotine Sulfate, 1.5 lbs. Soap	July 31	0	64.3
1 lb. 25% Lindane W.P.	July 31	0	59.8
1 pint 50% Systox Emul.	July 31	3.6	39.7
Untreated	—	—	79.7

[1] Corrected for varying mortality in checks, which averaged 9.1% mortality.
[2] 2 lbs. actual toxaphene per 100 gallons water.

Table 7.—Boxwood leaf miner May treatments against adults.

Formulation in 100 Gallons of Water	Date Sprayed	Miners in 100 Leaves	Mite Injury
2 lbs. 50% DDT W.P., 3.5 oz. Triton×100	May 28	97	slight
3 lbs. 50% DDT W.P.[1]	May 27	1	light
4 lbs. 50% DDT W.P., 3.5 oz. Triton×100	May 28	51	moderate
1 quart 25% DDT Emul.[1]	May 23	14	light
Average of Untreated	—	330	none

[1] Different locations, timing somewhat better than other treatments.

Table 8.—Boxwood leaf miner.

Formulation in 100 Gallons of Water	Date Sprayed	Miners per 100 Leaves	Stage Treated
1 lb. 15% Parathion W.P.[1]	June 21	42	Larva
1 lb. 15% Parathion W.P.	June 21	0	Larva
1.5 lbs. 15% Parathion W.P.	June 20	0	Larva
1 lb. 25% Parathion W.P.	July 17	0	Larva
1.5 lbs. 25% Parathion W.P.	June 3	0	Larva
1 Quart 63.3% Octamethyl Pyrophosphoramide	June 21	78	Larva
2 lbs. 12% Gamma Benzene Hexachloride W.P.	June 3	460	Larva
3 lbs. Chlordane (tech.), 1 gal.	July 17	17	Larva
1 Quart 25% DDT Emul.	May 23	14	Adult
1 lb. 15% Parathion W.P., 1 Quart 25% DDT Emul.	May 19	274	Egg
Untreated	(May 19, June 3)	705	
Untreated	(May 23, June 21)	137	
Untreated	(July 17)	600	

[1] Incomplete spray coverage, volume too low.

Table 9.—Arbor vitae leaf miner initial experiments.

Formulation in 100 Gallons of Water	Date Sprayed	Living per 10 Sprigs[1]
2 lbs. 50% DDT W.P.	June 18	9
2 lbs. 50% Chlordane W.P.	Aug. 30	51
1.35 lbs. 74% Chlordane Emul.	Aug. 30	80
Untreated	—	81

[1] Sprigs approximately 5 inches long.
June 18 timed against adults.
Aug. 30 timed against small larvae.

Table 10.—Arbor vitae leaf miner 1951 experiments.

Formulations in 100 Gallons of Water	Date Sprayed	Per Cent Mortality	Mines per Sprig[1]	Living per Sprig[1]	Mites per Sprig[1]
	Sept.				
5 lbs. 40% Chlordane W.P.	8	3.5	17.3	13.7	0.5
1 pint 50% Systox Emul.	8	14.0	13.6	9.7	0.3
2 lbs. 25% Lindane W.P.	8	26.9	12.7	7.2	1.0
2 lbs. 15% Parathion W.P.	8	98.3	13.7	0.1	5.1
	June				
2 lbs. 50% DDT W.P., 1 lb. 15% Aramite W.P.	23	3.4	1.7	1.3	78.0
Untreated	—	7.0	13.8	11.4	3.6

[1] Sprigs approximately 5" long.
June 23 timed against adults.
September 8 timed against small larvae.

in many cases. Spruce mite, *Paratetranychus ununguis* (Jac.), increase following DDT application to arbor vitae has been so severe in some cases as to outweigh the leaf miner control benefits. Blauvelt found that parathion and DDT gave equally good adult control in one experiment, so that parathion may be preferable as it is less likely to permit increase of spruce mite populations.

Table 9 indicates 1948 comparisons of treatments against adults and larvae. Counts were made in April 1949. The DDT adult treatment gave good but incomplete reduction of miners. Chlordane was ineffective applied against larvae.

Table 10 indicates 1951 results as observed in October. 0.3 lb. parathion in 100 gallons of water gave very high kills of larvae, and was superior to DDT adult treatment in terms of living miner population. However, adult control by DDT was good; and trees in these plots did not show the large number of browned small mines which developed during July and August before the parathion plots were treated. Chlordane and Systox were ineffective. 0.5 lb. lindane in 100 gallons of water was only slightly effective, so that lindane is not promising against arbor-vitae leaf miner.

The DDT treatments caused a great increase in spruce mite populations even though Aramite was included in the spray to control mites. The DDT treated trees were very conspicuous by late September through their yellowed, poor appearance. The mite injury in the DDT plots rendered the trees less attractive than they were in the check and other severely mined plots.

SUMMARY.—Birch, elm, holly, boxwood, and arbor vitae were sprayed with a number of the newer insecticides to determine efficiency against larval miners within the leaves. Comparisons were made to treatments applied against adults to prevent oviposition.

Five lbs. of 40 per cent chlordane wettable powder, 1 lb. of 25 per cent lindane wettable powder, and 0.5 pint of 50 per cent Systox emulsifiable solution per 100 gallons of water were very effective against birch leaf miner larvae. Treatments should be applied when the small brown spots of mines of first instar larvae become apparent. Control of the first generation only is insufficient for maintaining good tree appearance in small plantings.

Similarly, 4 lbs. of 40 per cent chlordane wettable powder, 1 lb. of 25 per cent lindane wettable powder, and 1 pint of 50 per cent Systox emulsifiable solution per 100 gallons of water were very effective against elm leaf miner larvae. Similar timing criteria are applicable as for birch. First generation control was sufficient for maintaining good tree appearance.

It is considered that lindane is the most practical of the insecticides which were found to be effective against miners on birch and elm.

None of the insecticides tested was effective in controlling larval holly leaf miners. DDT adult treatment was effective.

One lb. of 15 per cent parathion wettable powder in 100 gallons of water was effective in some cases against boxwood leaf miner larvae but 1.5 lbs. and higher was consistently completely effective by one spraying. No other insecticide tested was completely effective. DDT adult treatments gave very good but incomplete control.

Two lbs. of 15 per cent parathion wettable powder per 100 gallons of water was highly effective against arbor-vitae leaf miner larvae by one spraying. No other insecticide tested was effective. DDT treatment against adults was very effective, but spruce mite injury was greatly aggravated even though an acaricide was included.

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Spruce Mite and Southern Red Mite Control Experiments

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Southern red mite, *Paratetranychus ilicis* McG., and spruce mite, *Paratetranychus ununguis* Jac. are the two most common and destructive mites of evergreens in New York State. Southern red mite is most injurious on broad leaf evergreens such as holly and azalea and is also found on some deciduous plants. Spruce mite is the only phytophagous mite that has been found by the authors on conifers.

The usual population trends on these mite species have an important bearing on their control. Hatching of overwintering eggs occurs in late April and early May. High winter egg populations usually produce high motile mite populations by late May with a peak in June. During June much of the population migrates to new growth. Injury to the old growth is usually very noticeable by the time that migration takes place and continues to become more severe as the season progresses. The new growth begins to exhibit typical mite injury soon after becoming infested and by late June or early July may be severely injured. Such mite populations usually decline repidly during late June or July. Populations may increase rapidly during the summer in some plantings. In September the population usually increases again and large numbers of overwintering eggs are oviposited. Mite injury effects become most noticeable during the summer even though populations may be decreasing or low.

Investigations were initiated in 1948 on the control of mites on woody ornamental plants. In general single sprays of acaricides were applied during mid-May when mite populations were increasing. It was expected that such single early applications of some of the newer residual acaricides would prevent mite damage during the usual spring season of mite activity. Some of the 1948, 1949, and early 1950 work was reported by Matthysse & Naegele (1950). Di p-chlorophenyl methyl carbinol (TM-1), EPN and p-chlorophenyl p-chlorobenzene sulfonate (TM-2) were the only acaricides that evidenced very good residual action against southern red mite and spruce mite. Schradan parathion, tetraethyl pyrophosphate and a piperonyl cyclonene-pyrethrum-rotenone combination evidence very short residual action. Lime sulphur gave good residual action against spruce mite but was somewhat phytotoxic. TM-1, EPN, and TM-2 having given excellent results, were included in late 1950 and 1951 experiments. Emulsions were compared to suspensions, and several concentrations included. Aramite was included as newer and supposedly more stable formulations were available. Systox (di ethoxy thiophosphoric ester of S-ethyl mercapto ethanol) A selenium compound (1.03 per cent selenium as potassium ammonium seleno sulfide), special wettable sulphur, and emulsifiable toxaphene previously untested by the authors, were also included.

METHODS AND MATERIALS—Nursery plantings of azalea, *Rhododendron* sp., Norway spruce, *Picea abies* (L.), and American holly, *Ilex opaca* Ait., on Long Island were treated using a 50-gallon tank, 4 horsepower, 7 gallon per minute

Table 1.—Southern red mite population trends following May 15, 1951 treatments of azalea in frames at Farmingdale, N. Y.

Formulation/100 Gallons Water	Per Cent Mortality, 1 Day	Living Mites per 10 Leaves						
		Pre-spray	1 Day	4 Days	8 Days	14 Days	30 Days	45 Days
1 lb. 15% Aramite W.P.	95.4	11.2	0.6	1.6	1.6	1.4	1.2	0.0
1 lb. 50% TM-2 W.P.	90.7	21.6	2.2	6.4	3.4	0.4	0.0	0.3
35 liq. oz. 3 1012 TM-2 Emul.[1]	81.0	14.8	2.8	7.2	4.6	4.6	0.6	0.0
1 pt. 25% TM-1 Emul.	100.0	10.8	0.0	0.0	4.8	15.4	0.0	2.1
1 qt. Seleneum Emul.	58.1	8.6	3.6	5.6	22.4	85.4	0.2	0.0
1 pt. 50% Systox Emul.	95.3	30.0	1.4	11.4	44.6	131.2	1.0	0.4
No Treatment	6.5	39.8	36.5	72.0	71.8	35.5	6.5	1.6
LSD 5%		16.5	8.8	15.2	20.8	57.8	2.3	1.4

[1] C 1012 contains 1.8 lbs. K 6451 (p-chlorophenyl p-chloro-benzene sulfonate) per gallon, therefore spray contained 0.5 lb. K 6451 per 100 gallons water.

power sprayer. Three or four nozzle brooms were used in the work, and pressure maintained at 350 lbs. per square inch. A sufficient volume was sprayed on the plants to allow complete coverage and some run-off. Locally available commercial wettable powders and emulsifiable solutions were used as indicated in the tables. Special formulations of some of the toxicants were supplied for experimental purposes by the manufacturer. Included were on Aramite emulsifiable solution containing 4.8 lbs. Aramite per gallon, a 40 per cent TM-1 wettable powder, and TM-2 emulsifiable solution (Code C1012) containing 1.8 lbs. TM-2 per gallon.

Experiments conducted against southern red mite on azalea were carried out in nursery frames containing 18 to 24 inch azaleas. Numbers of mites were recorded from 25 random leaves picked from five random twig tips from each replicate. Experiments conducted against southern red mite on American holly were carried out in a planting of 81, 4 to 5 foot holly placed 25 feet apart. The numbers of mites on three leaves from each of nine trees were recorded from each replicate. Tests conducted against spruce mite on Norway spruce were carried out with 3 to 4 foot spruce in a nursery row. Random samples of three 4-inch twigs were collected from each of three trees in each replicate and the number of mites recorded.

In each of the tables a pre-spray count is recorded which is the sum of dead and living from the 1-day mortality count. The treatment pre-spray counts are always lower than for the check because of the tendency of dead mites to fall off.

RESULTS AND DISCUSSION.—Table 1 indicates results obtained against southern red mite in the azalea plot. The azalea had been under glass in cold frames during the winter, and the glass removed a week before treatment. The check population at treatment time included eggs, nymphs and adults. The population began to decrease beyond 8 days after treatment and reached a low level by 1 month after treatment. One pound of 15 per cent Aramite wettable power, one pint of 25 per cent TM-1 emulsifiable solution, and one pint of 50 per cent Systox emulsifiable solution, each in 100 gallons of water, gave complete kill within 1 day. 8 oz. actual TM-2 in 100 gallons of water gave a somewhat lower initial mortality, with the suspension slightly superior to the emulsion. One quart of selenium compound in 100 gallons of water was inferior to initial kill. Heavy rains beyond the initial 1-day count period subjected the treatments to a severe test. TM-1 gave fewer than 8 days residual action and was not satisfactory by this single treatment. Although Aramite, at this low concentration, never completely eliminated the mite population, there was no serious population increase in these plots. The 4 and 8 day counts comprised entirely live larvae and nymphs which had hatched following treatment. TM-2 did not eliminate adult mites, but very few larvae hatched and survived so that populations gradually decreased and over-all control was very good for the whole test period. The selenium compound and Systox never eliminated motile mites, and poor residual action allowed rapid population increase beyond 4 days.

Table 2 indicates results obtained against southern red mite-infested Ameri-

Table 2.—Southern red mite population trends following May 21, 1951 treatments of American holly at Manorville, N. Y.

Formulation/100 Gallons Water[1]	Per Cent Mortality, 1 Day	Living Mites per 10 Leaves						
		Pre-spray	1 Day	4 Days	7 Days	22 Days	42 Days	56 Days
1 lb. 15% Aramite W.P.	100.0	17.2	0.0	1.4	32.6	332.2	791.1	65.8
4 liq. oz. Aramite Emul.[2]	100.0	7.2	0.0	0.0	10.3	14.8	116.3	23.7
1 lb. 50 TM-2 W.P.	45.8	13.3	7.2	14.1	11.8	29.6	7.8	5.2
35.0 liq. oz. C 1012 TM-2 Emul.[3]	85.8	58.9	8.3	3.3	0.0	21.4	40.3	25.6
1 pt. 25% TM-1 Emul.	100.0	7.2	0.0	0.0	0.0	19.6	44.8	27.8
9.5 liq. oz. 25% Parathion Emul.	96.1	99.4	4.4	0.3	31.8	313.0	677.0	162.2
Check, DDT only	19.3	129.4	105.0	50.6	65.1	566.1	507.3	30.8
LSD 5%		147.4	74.2	15.4	52.9	162.7	549.6	72.1

[1] Every treatment included 1 lb. actual DDT per 100 gallons of water for holly leaf miner control.
[2] Emulsifiable Aramite contained 4.8 lbs. Aramite, beta-chloroethyl beta-(p-tert butylphenoxy)-alpha-methyl ethyl sulfite, per gallon. Spray, therefore, contained .15 lb. technical Aramite per 100 gallons water.
[3] C 1012 contains 1.8 lbs. K 6451 (p-chlorophenyl p-chloro benzene sulfonate) per gallon, therefore, spray contained 0.5 lb. K 6451 per 100 gallons of water.

can holly after treatment in May. Low acaricide concentrations were used in order to accentuate differences in residual activity of the various formulations. The population at treatment time consisted of adult mites with many unhatched summer eggs. The check population decreased during the first week as old adults died off, but rose quickly as eggs hatched about 7 days after treatment. One pint 25 per cent TM-1 emulsifiable solution and 0.15 pound actual Aramite each in 100 gallons of water gave complete kill of the adult mites while parathion emulsion at the concentration used gave almost complete kill. The poorest kill was exhibited by TM-2 with the emulsion somewhat better than the wettable power. In the check plot treated with DDT only, there was a slight mortality. Aramite evidenced poor residual action allowing the population to begin to rise, through egg hatch, within 7 days of treatment. The emulsion gave somewhat longer residual action than the wettable powder. One half pound actual TM-2 in 100 gallons of water gave less than 22 days residual action as evidenced by successful establishment of larvae and nymphs. However, the populations never rose to a high level. The wettable powder appeared to be superior in preventing population increase; however the emulsifiable form more quickly reduced the initial adult mite population. TM-1 evidenced residual action and population trends similar to that of TM-2, except for the more rapid initial kill by TM-1. Parathion emulsion never reduced the population completely and had poor residual action.

Within 2 months after treatment no mite injury was apparent on the 1951 growth of plants treated with TM-2 wettable powder. Only slight mite injury was apparent on TM-1 and TM-2 emulsion treated plants. The check and Aramite-treated plants exhibited moderate mite injury while parathion treated plants exhibited severe mite injury.

Table 3 indicates the results obtained from treating southern red mite-infested American holly in July. The plants used in this experiment were the same as those used to obtain the data in the previous table. However, plots were rearranged and relocated to compensate for the population variations. At treatment time the population consisted of larvae, nymphs and adults as well as numerous eggs. The check populations remained high for at least 11 days after the treatment date but decreased beyond this time. 0.3 pound actual Aramite as emulsion, one pint 25 per cent TM-1 emulsifiable solution, and one pint 50 per cent Systox emulsifiable solution each in 100 gallons of water gave complete kill of all stages within one day. Two pounds of 15 per cent Aramite wettable powder in 100 gallons of water gave very good, but incomplete kill while 0.5 pound 25 per cent EPN wettable powder in 100 gallons of water gave lower kill than the other materials. The July treatments appeared to subject the acaricides to a more severe test as residual activity was shorter than in May. Aramite and

Table 3.—Southern red mite population trends following July 16, 1951 treatments of American holly at Manorville, N. Y.

Formulation/100 Gallons Water	Per Cent Mortality, 1 Day	Living Mites per 10 Leaves					
		Pre-spray	1 Day	4 Days	11 Days	30 Days	60 Days
2 lbs. 15% Aramite W.P.	98.7	56.3	0.7	7.0	30.3	44.4	124.0
8 liq. oz. Aramite Emul.[1]	100.0	74.4	0.0	4.0	16.7	32.2	77.8
0.6 lb. 40% TM-1 W.P.	100.0	46.7	0.0	8.1	21.1	16.7	61.4
1 pt. 25% TM-1 Emul.	100.0	38.9	0.0	1.4	10.7	41.1	58.9
0.5 lb. 25% EPN W.P.	92.3	10.6	1.0	2.9	1.7	1.7	2.3
1 pt. 50% Systox Emul.	100.0	18.1	0.0	0.0	0.0	1.1	1.4
No Treatment	14.7	111.7	98.7	182.5	197.9	18.3	26.6
LSD 5%		93.2	32.0	16.2	58.8	40.5	49.8

[1] Emulsifiable Aramite contained 4.8 lbs. Aramite beta-chloroethyl beta-(p-tert butylphenoxy)-alpha-methyl ethyl sulfite per gallon. Spray, therefore, contained 0.5 lb. technical Aramite per 100 gallons of water.

TM-1 gave less than 4 days residual action, allowing rapid mite increases thereafter. EPN never completely eliminated the population but kept it low throughout the test period. Systox prevented reinfestation for at least 11 days after which a few mites appeared in the plot. However, the population of the EPN and Systox plots was low when they were treated.

Within two months after treatment a slight increase in the severity of mite injury had occurred in every plot except EPN and Systox.

Table 4 indicates the results obtained from threating spruce mite-infested Norway spruce in May. The population at treatment time consisted mainly of adults. The 8-day count showed the check population to be decreasing as old adults died off, but a rapid increase followed as first generation eggs hatched, and remained high through the observation period. Two pounds of 15 per cent Aramite wettable powder and one pint of 50 per cent Systox emulsifiable solution, each in 100 gallons of water, gave complete kill within 1 day, while 1 pint of 25 per cent TM-1 in 100 gallons of water gave almost complete kill. One quart of the selenium compound in 100 gallons of water was almost equal to TM-1 in initial kill. TM-2 at the concentrations used gave low initial kill. However, 2 pounds of 50 per cent TM-2 wettable powder in 100 gallons of water gave more rapid adult kill than 1 pound. TM-2 evidenced the best residual activity preventing establishment of larvae so that as soon as the adults were eliminated the population decreased to zero, and the plants were still uninfested 45 days after treatment. By 117 days after treatment the TM-2 plots had become reinfested. TM-1 did not eliminate the population but prevented any great increase for over 30 days. Aramite evidence short residual action allowing the population to build up after 8 days. Systox evidenced less than 8 days residual action. The selenium compound was inferior, as evidenced by high populations within 15 days of treatment.

Within two and one-half months after treatment there was very little mite injury on the new growth of those plants treated with TM-2 or TM-1. However, the new growth of those plants treated with Aramite, or the selenium compound, as well as the check had considerable mite injury.

Table 4.—Spruce mite population trends following May 14, 1951 treatments of Norway spruce at Farmingdale, N. Y.

Formulation/100 Gallons Water	Per Cent Mortality, 1 Day	Living Mites per 10 Twigs							
		Pre-spray	1 Day	3 Days	8 Days	15 Days	30 Days	45 Days	117 Days
2 lbs. 15% Aramite W.P.	100.0	876.1	0.0	0.0	0.6	69.3	55.7	167.8	93.9
1 lb. 50% TM-2 W.P.	67.8	286.7	98.9	131.1	70.5	26.7	0.0	0.0	31.7
2 lbs. 50% TM-2 W.P.	47.8	416.2	174.7	52.2	5.8	1.0	0.0	0.0	58.3
1 pt. 25% TM-1 Emul.	99.6	448.9	1.7	1.1	0.6	7.3	15.7	140.0	77.2
1 qt. Selenium compound	95.9	411.7	27.8	8.9	2.1	240.0	177.7	118.3	48.3
1 pt. 50% Systox Emul.	100.0	486.7	0.0	0.0	8.3	56.7	—[1]	—	—
No treatment	13.3	425.2	356.0	432.6	106.5	776.0	233.0	206.0	173.7
LSD 5%		232.8	129.8	158.4	35.8	427.1	129.0	107.8	58.5

[1] Treated by owner prior to this date.

Table 5.—Spruce mite population trends following August 14, 1950 treatments of Norway spruce at Farmingdale, N. Y.

Formulation/100 Gallons Water	Per Cent Mortality, 1 Day	Living Mites per 10 Twigs				
		Pre-spray	1 Day	6 Days	Fall 41 Days	Spring 266 Days
4 lbs. Wettable Sulphur	70	54.0	18.0	1.4	146.0	334.8
2 qts. Selenium comp.	91	43.7	3.6	0.7	5.4	36.1
1 pt. 25% TM-1 Emul.	94	17.7	1.2	1.0	16.0	264.3
1 qt. 50% Toxaphene Emul.	60	28.9	11.1	3.6	724.1	2229.0
No Treatment	1	78.5	77.5	147.9	647.9	1253.4
LSD 5%		73.3	69.4	30.8	1,718.3	1593.4

Table 5 indicates the results obtained from treating spruce mite infested Norway spruce in August 1950. At treatment time the population on untreated plants was high and increased during the observational period. The following spring the population was very high due to the large number of overwintering eggs oviposited by the high fall population. One pint 25 per cent TM-1 emulsifiable solution and two quarts of the selenium compound solution each in 100 gallons of water gave high mortality within 1 day. Four pounds wettable sulphur, and one quart 50 per cent toxaphene emulsifiable solution, each in 100 gallons of water, gave poor initial kills. The selenium compound and TM-1 exhibited very good residual action keeping the population low for at least 41 days after treatment. Toxaphene and sulfur gradually reduced the population for 6 days but was a great increase beyond this date. The effect of August treatments on the fall populations were directly reflected in the following spring populations.

SUMMARY AND CONCLUSIONS.—Azalea, holly, and spruce were treated for control of spruce mite and southern red mite. Single applications were made and mortality and populations recorded during a period of at least six weeks following treatment.

Di p-chlorophenyl methylcarbinol (TM-1), parathion, Systox, Aramite, and EPN, and the higher concentration of selenium all produced high mortality of motile mites within one day of treatment. Toxaphene, wettable sulphur, and the lower concentration of the selenium compound gave inferior immediate kill. P-chlorophenyl p-chlorobenzene sulphonate. (TM-2) was very slow acting against large motile mites.

Toxaphene, wettable sulphur, parathion, and the lower concentration of selenium compound evidenced very short residual action, so that they were ineffective in preventing mite population build-up.

Aramite and TM-1 were variable in residual effectiveness, evidencing inferior residual action in experiments were tests conditions were severe (low concentration, excessive rain fall, midsummer temperature and humidity). TM-1 residual activity in most cases was sufficient to prevent mite build-up for more than a month. Aramite in emulsion form gave somewhat longer residual action than suspensions, but was inferior to TM-1 and TM-2 at the concentrations tested.

TM-2 consistently gave long residual action. In all experiments TM-2 treatments prevented excessive mite build-up for the complete observational period. It is considered that TM-2 satisfies the requirements necessary for single application control of spruce mite and southern red mite.

EPN was included in only one experiment, and evidenced excellent residual action, so that it is very promising.

Systox was very variable in residual effectiveness, and more work on plant species and growing conditions at spraying time is necessary before conclusions can be drawn.

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Field Tests of Insecticides for Control of Oriental Fruit Fly

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In less than a year investigations in Hawaii[1] have indicated that excellent control of the oriental fruit fly, *Dacus, dorsalis* Hendel, with insecticides is a definite possibility. Several of the new organic materials have shown unusual promise in the laboratory and in limited field tests on banana and guava. Tests on a larger scale and on a wider variety of hosts are needed for a full evaluation of the practical usefulness of these materials. Although performance on crops grown in Hawaii is no guarantee that the insecticides will work as well in continental United States, fruit and vegetable growers now have some assurance that an effective insecticide will be available should the oriental fruit fly escape detection at ports of entry and become a pest in mainland areas.

The oriental fruit fly is a stong flier and its populations are far from static. Control efforts must often be directed against immigrating flies. A satisfactory insecticide must be toxic enough to kill the females coming into contact with the residues for the first time when they attempt oviposition, yet the residues must not be dangerous to human or animal life. The experimental insecticides were selected with these characteristics in mind. Laboratory screening tests had demonstrated their outstanding residual action, and all of them proved to be extremely effective direct contact poisons that could be used successfully as such at unusually low application rates per acre.

Crops suitable for laying out plots of adequate size and acceptable design in well randomized experiments are rare in Hawaii. Most of the relatively few large plantings of cultivated hosts, such as bananas, papaya, avocado, and mango, are either under irrigation with the individual plants too close together, or they are nonuniform as to variety and time of ripening. Wild guava, the most important host, is generally located on mountain slopes or in deep meandering gulches. After extensive surveys had been made to determine the most suitable experimental sites, satisfactory locations were found and two series of tests were set up, one on cultivated bananas and the other on wild guava.

Fly infestations in the test plots were estimated periodically by collecting all ripe fruit from certain record plants. The fruit samples were weighed and held for 30 days over sand in standard holding boxes. The dead and living larvae and pupae were screened out of the sand at weekly intervals. The total number of larvae per pound of fruit provided the infestation index that was used to estimate the control obtained. This index failed to take into account the mortality of larvae or eggs in the fruit or the number of oviposition punctures. The latter was not important, however, as the number of egg punctures is not a reliable infestation index because of the tendency of ovipositing females to use old oviposition sites. At infestation levels of 15 or more larvae per pound, not less than 80 per cent of the fruit in 20-fruit samples have produced larvae.

In small-plot tests, such as those reported here, reductions of infestation of 80 per cent may be considered to represent good performance and those above 90 per cent outstanding performance.

Except where otherwise indicated, insecticides used in the tests were all proprietary formulations. The abbreviation "WP" refers to a wettable powder, and "EM" to an emulsifiable formulation. The figures preceding these abbreviations indicate the percentages of active oxicant. All concentrations in tables and text refer to the percentages of active ingredient rather than to the amount of the formulated material. The CS-708 (or Dilan) 50 per cent wettable-powder formulation contained 50 per cent of a 1:2 mixture of 50 per cent wettable-powder formulation contained 50 per cent of a 1:2 mixture of 1,1-bis-(*p*-chlorophenyl)-2-nitropropane, known as CS-645A (Prolan), and 1,1-bis-(*p*-chlorophenyl)-2-nitrobutane, known as CS-674A (Bulan). The DDT 97 per cent wettable-powder formulation was reported by the manufac-

[1] Organization of the oriental fruit fly research program in Hawaii has been described by Carter (1950).

turer to contain the indicated amount of DDT. The aldrin emulsifiable concentrate contained 40 per cent of a 60 per cent aldrin equivalent solution, 45 per cent of xylene, and 15 per cent of polyoxyethylene sorbitol oleate-laurate. The dieldrin emulsifiable concentrate contained 27.5 per cent of technical dieldrin (91.5 per cent purity), 57.5 per cent of xylene, and 15 per cent of the same emulsifier as the aldrin.

EXPERIMENTS ON BANANAS.—The first series of tests was conducted on Cavendish bananas, a low-growing variety that was planted in rows 3 to 5 feet apart. The plots were distributed along accessible roadways in a restricted randomization with three replicates of each treatment. Each plot was 100 feet or more in length and usually 40 to 60 feet wide. The replicates of an unsprayed check plot were located slightly apart from replicates of sprayed plots, but each of the sprayed plots was bounded on one or more sides by an unsprayed area.

For record purposes, three bunches of fruit were allowed to ripen in each plot. When the fruit on one bunch was exhausted in the process of determining fruit fly infestations, another bunch (three-fourths grade) was marked to replace it. Thus the sample bunches were largely the sole target for arriving flies and the attack was most intensive and concentrated on the banana fingers that broke color first. Furthermore, since all ripe fruit was removed at weekly intervals, fly attacks on the sample bananas were concentrated towards the ends of 7- and 14-day intervals after spray applications.

The results of a limited study of the variability among samples, each consisting of 20 field-ripened bananas, indicated that samples of 62, 88, and 200 bananas would have been required to reduce the standard error to 10 per cent of the mean when the respective infestations approximated 117, 61, and 33 larvae per pound of fruit. Despite the large standard errors in the 20-fruit samples, sample size could not be increased to more than 30 bananas because of space limitations in the holding boxes. The small size of the samples was partially compensated for by increasing the number of samples taken from each plot.

Eight sprays were applied between March 13 and August 8 at approximately 2-week intervals except for a 40-day lapse between the fourth and fifth sprays. Conventional dilute spray equipment devel-

Table 1.—Results of insecticide tests for control of the oriental fruit fly on Cavendish bananas. Mokuleia, Oahu, Hawaii. 1950.

Formulation	Pounds of Toxicant per Acre	Average Per Cent Reduction in Larvae per Pound of Fruit at Indicated Intervals After Treatment				Mean Per Cent Reduction
		March 20 to May 11		June 14 to August 8		
		1 Week	2 Weeks	1 Week	2 Weeks	
CS-708 50 WP	5.25	94	90	97	93	94
DDT 97 WP	5.10	89	86	90	98	91
DDT 50 WP	5.25	85	78	98	99	90
Parathion 25 WP	2.20	87	49	96	98	82
DDT-xylene[1]	5.25	76	63	92	80	78
DDT 50 Paste+EPN 25 WP	3.50+0.55	71	52	—	—	
DDT WP+EPN 25 WP	3.50+0.55	—	—	93	92	
EPN 25 WP	2.20	54	58	98	94	76
DDT 50 Paste	5.25	81	48	92	78	75
Aldrin 25 WP	2.20	60	60	84	66	68
Aldrin 24 EM	2.20	68	70	40	57	59
Dieldrin 25 WP	2.20	35	40	68	84	57
Dieldrin 25 EM	2.20	35	53	57	64	57
DDT 50 WP+oil[2]	5.25+7 pt.	—	—	96	91	—
Parathion 25 WP+raw sugar	0.4+48	13	13	—	—	—
Mean larvae per pound of fruit in unsprayed plots		81	129	13	27	

[1] An emulsifiable formulation of DDT (tech.) 1 lb., xylene 1 qt., and Triton B-1956, not necessary now over 0.5 oz.
[2] Orthol K emulsion.

oping a pressure of 550 pounds per square inch was used. The spray was a driving fog applied with a single gun operated from the top of the sprayer at the rate of 18 to 20 gallons per minute.

The materials tested and the results calculated according to Abbott's formulas are given in table 1.

The data in table 1 are weighted infestation indices in which the total number of larvae were divided by the total banana production in all plots receiving the same treatment for the periods indicated in the table.

The differences in performance of the materials prior to May 11 and after June 14 were believed to be due to differences in rainfall, since mean temperatures fluctuated within the same narrow range of approximately 65° to 75° F. The average precipitation during the first 2 weeks following each of the first four sprays was 1.80 inch compared with only 0.12 inch per 2-week period thereafter. The effect of the heavier rainfall was most noticeable on the parathion treatment.

The dilan and two of the DDT treatments were the most effective, and they had the best residual action during the March to May period. In dry weather parathion and EPN were also highly effective and each had good residual action even at less than half the concentration of DDT. At comparable application rates each of these materials was superior to both wettable-powder and emulsifiable formulations of dieldrin and aldrin, which gave rather poor results in these field tests. Aldrin was somewhat better than dieldrin in rainy periods.

The parathion-sugar bait spray, suggested by the work of Myburgh & Stubbings (1950), was ineffective.

Although situated from 30 to 50 yards away from sprayed plots, the replicates of the unsprayed plot showed the influence of the sprays. In these plots there was a decline in infestation in nearly all 7-day samples that was followed by a substantial increase therefater until the time the next spray was applied (Table 1), probably because of fly movement among the plots.

RESIDUAL EFFICIENCY OF SPRAYS APPLIED TO BANANA.—Flies were exposed to three sections cut from different banana leaves to compare the residual efficiencies of the insecticides. The leaves were masked so that only 28 sq. cm. of leaf surface was exposed on each. This space amounted to about 6 per cent of the interior of the cage surface. The upper leaf surfaces were exposed to the flies in half the cages and the lower surfaces in the remainder. A total of 125 to 200 flies was used for each determination. The flies were fed sugar, water, papaya juice, and an enzymatic hydrolysate of yeast. They were held in the cages 48 hours and mortality was determined at the end of this period. This method tended to underestimate the residual effectiveness of the insecticides under field conditions, because the flies in the sprayed plots had less opportunity to find surfaces free of insecticide there than they had in the cage tests. There was also less opportunity for them to consume food and water free of insecticidal contamination in the field plots.

The results of these studies are summarized in table 2. They indicate that dieldrin and aldrin wettable powders are comparatively good residual toixcants and that they should have performed much better than DDT in the field, even at the lower application rates. Reasons for their failure to do so in the field tests remain to be determined. Dieldrin, aldrin, and DDT emulsifiables had less residual effectiveness than the wettable powders, but the contact effect of both types of formulations was sufficient to kill practically all flies present in sprayed areas at the time of application. This suggested that treatment differences probably did not begin to develop under field conditions until newly emerged flies had

Table 2.—Residual efficiency of spray deposits on banana foliage exposed to caged flies.

FORMULATION	POUNDS OF TOXICANT PER ACRE	PER CENT MORTALITY ON INDICATED DAYS AFTER SPRAYING			
		1 Day	7 Days	14 Days	Average
Sprays 1 to 4					
Dieldrin 25 WP	2.20	80	47	16	48
Aldrin 25 WP	2.20	39	31	22	31
CS-708 50 WP	5.25	39	33	13	28
Dieldrin 25 EM	2.20	61	15	4	27
Parathion 25 WP	2.20	62	10	4	25
DDT 50 WP	5.25	46	17	7	23
EPN 25 WP	2.20	49	9	6	21
Aldrin 24 EM	2.20	8	9	3	7
Check—Untreated	0	6	6	5	6
Sprays 5 to 7					
DDT 50 Paste	5.25	58	46	13	39
DDT 50 WP+oil	5.25+ 7 pts.	42	34	18	31
DDT 50 WP	5.25	48	23	8	26
DDT-xylene EM	5.25	22	15	9	16
DDT 97 WP	5.10	23	14	6	14
Check—Untreated	0	2	3	3	3

Table 3.—Results of insecticide tests for control of the oriental fruit fly in guava plots. Honolulu, Hawaii, 1950.

Plot No.	Formulation	Pounds of Toxicant per Acre	Per Cent Control				Per Cent of Parasitization
			Entire Crop[1]	Days After Spraying[2] 7	14	21	
16	Parathion 25 WP	1.70	96	99	96	87	26
12	Aldrin 25 WP	0.85	89	96	86	70	11
10	Dieldrin 25 WP	0.85	89	98	73	70	4
6	DDT 50 WP	2.25	88	94	81	85	50
	+ Parathion 25 WP	0.14					
17	EPN 25 WP	1.40	87	98	83	65	52
13	Aldrin 25 WP	1.70	84	97	90	11	9
8	Dilan 50 WP	3.40	82	94	81	48	37
9	Dilan 25 EM	1.70	81	96	74	36	69
18	Lindane 25 WP	0.85	78	85	84	45	28
3	DDT-50 WP	2.25	77	91	62	60	28
7	Dilan 50 WP	1.70	74	93	88	32	26
11	Dieldrin 25 WP	1.70	68	86	54	43	2
5	DDT-75 WP	2.25	64	79	68	2	56
14	Aldrin 24 EM	0.85	60	75	55	24	7
15	Parathion 25 WP	0.85	57	86	30	0	39
4	DDT 50 WP	2.25	36	77	9	0	27
	+Oil	2.25 (qt.)					
Least significant difference Odds 19:1			17	15	23	35	—
Larvae per 100 lb. in unsprayed plots			288	378	255	164	—

[1] Based on the mean of the 3 infestation indices derived from total production, disregarding days after spraying. Pounds of fruit produced on the 9 record guava trees ranged from 404 to 1193 per treatment.
[2] Based on mean of infestation indices derived from total production on 4 dates for the 7- and 14-day periods and on 3 dates for the 21-day period.

reached sexual maturity, or until some of the mature migrating female flies could withstand the reduced effectiveness of the partially weathered residues.

EXPERIMENTS ON GUAVAS.—Field tests on guava plots located on sloping terrain 600 to 750 feet above sea level were set up in June 1950. The plots consisted of three replicates of each spray treatment and six of the unsprayed check. Each replicate was approximately 100 feet wide and 100 to 200 feet long, or about one-third acre in size. They were arranged in a restricted random arrangement.

The sprays were applied with conventional dilute spray equipment on June 28, July 13, August 3, and August 23, at the rate of 225 gallons per acre per application. A pressure of 600 pounds per square inch and a delivery rate of 30 gallons per minute from two guns were employed. The volume was insufficient to thoroughly wet all vegetation, but a special effort was made to distribute the spray uniformly. The equipment passed through the middle of each replicate, with the spray covering a swath of about 50 feet on each side.

For sampling purposes three areas of about 200 square feet each under guava trees near the center of each replicate were cleared of weeds and underbrush. On sampling dates all ripe fruit on or under these guava trees was picked, counted, and mixed thoroughly, and then a sample of 60 guavas from each plot was withdrawn. The samples were placed in holding boxes until all the surviving larvae had matured. Data thus made available included total yields of fruit, number of larvae, and the mean number of larvae per pound of fruit for each elapsed period between sampling dates. Sampling was started as the summer crop began to ripen—10 days before the first spray was applied—and it was continued at weekly intervals.

In mid-August, after it became evident that fly populations in replicates of the check plot were depressed by nearby spray applications, five supplemental unsprayed areas located 100 to 200 yards to the northwest, southwest, south, east, and northesat of the experimental area were also sampled each week. The control data, calculated on the basis of infesta-

tions in the six unsprayed replicates, were conservative estimates of the effectiveness of the insecticides, since infestations in the outlying areas were two to four times as high as those in the six check replicates.

To provide estimates of adult fly abundance and activity, 10 standard glass invaginated traps were operated in the unsprayed guava around the borders and within the experimental area. These traps were baited with a solution containing 8 per cent raw sugar, 0.13 per cent white vinegar, and 0.04 per cent yeast.

The results of these tests are given in table 3. They show that less insecticide per acre was required on guava than on banana for good control of the oriental fruit fly. Better spray coverage and larger plots were only partly responsible for the improvement in the performance of the materials. In the guava plots there were many host fruits suitable for oviposition in addition to those on the trees from which the samples were taken, and the attacks of the flies were not concentrated on the samples. Undoubtedly the percentage of flies killed before they reached the sample fruits was far greater in the guana plots than in the banana plots.

In the guava tests yields did not vary enough to influence results. The location of the plots was important, however, and this factor may have accounted for the poor control obtained with the high rate of application (1.7 lb.) of dieldrin and aldrin wettable powders (plots 11 and 13 compared with 10 and 12). As more flies began to drift downwind into the treatment area in August as a result of larger, upwing infestations, replicates of plots 5, 8, 9, 11, 14, 15, and 16, located across the windward side of the experimental area, were the first to be entered. The result was large infestation increases in all except the parathion replicate of plot 16. The latter retained the high efficiency of the other two parathion replicates despite the incoming flies, and parathion was the outstanding treatment with 96 per cent control. Its performance on guava paralleled that of 2.2 pounds of 25 per cent parathion wettable powder on bananas during the same part of the season, even though rainfall in the guava area was much heavier, averaging 2.84 inches during the four post-spray sampling periods. There was reason to believe that as parathion resi-

Table 4.—Guava and larvae production in sprayed and unsprayed plots, 1950 summer crop.

Date	Pounds of Fruit on 162 Plants	Number of Larvae per 100 Pounds of Ripe Guavas			Number of Female Flies per Trap Day
		From Sprayed Plots	From Unsprayed Plots	From Outside Supplemental Check Plots	
Pre-spray					
June 19	143	3105	4300	—	—
27	62	693	167		1.9
Spray 1					
June 28					
July 5	413	40	147	—	0.3
12	942	0	0	—	0.2
Spray 2					
July 13					
19	1270	0	0	—	0.8
26	2288	1	26	—	0.7
Aug. 2	2211	4	34	—	2.8
Spray 3					
Aug. 3					
9	2278	2	55	—	2.8
16	1712	11	78	—	3.5
22	599	330	499	1907	11.6
Spray 4					
Aug. 23					
30	638	270	1455	3148	4.9
Sept. 6	238	1313	3320	4755	9.4
13	85	811	407	1792	10.5
Post-spray[1]					
Sept. 27	46	749	633	195	3.0
Oct. 11	76	1426	1144	185	8.7
25	276	1510	1498	1724	6.2

[1] Guavas began producing their Fall crop late in September.

dues became too small to kill the flies that rested on or crawled over them, they still functioned by poisoning the food or water consumed by the flies on the sprayed surfaces.

When applications were made at the rate of 0.85 pound per acre, parathion in a wettable powder (plot 15) gave poor results and there was a rapid loss of residual efficiency. Other wettable powders containing EPN (plot 17) applied at the rate of 1.40 pounds per acre, dieldrin (plot 10), and aldrin (plot 12) at the rate of 0.85 pound per acre, and the combination of DDT 50 at 2.25 pounds plus parathion 25 at 0.14 pound (plot 6) all ranked high largely because their residual action held up for 21 days. At comparable application rates DDT 50 wettable powder apparently was superior to a 75 per cent DDT wettable-powder formulation. The addition of oil greatly depressed the effectiveness of the former. On guava as on banana, DDT and Dilan seemed to be about equal in performance when allowance was made for the difference in rates of application. Lindane 25 per cent wettable powder, when applied at the rate of 0.85 pound of toxicant per acre, was as good as DDT 50 per cent wettable powder at the rate of 2.25 pounds per acre in this experiment.

Table 5.—Residual efficiency of spray residues on guava foliage. Average of results following four spray applications.

Formulation	Pounds of Toxicant per Acre	Per Cent Mortality on Indicated Days After Spraying				
		0 Days	7 Days	14 Days	20 Days	Average
Dieldrin 25 WP	0.85	97	40	3	1	35
EPN 25 WP	1.40	91	27	17	5	35
Aldrin 25 WP	0.85	68	21	7	11	27
Parathion 25 WP	0.85	93	2	3	3	25
Lindane 25 WP	0.85	87	1	1	2	23
CS-708 50 WP	1.70	54	23	8	4	22
DDT 50 WP	2.25	43	12	4	4	16
CS-708 25 EM	1.70	14	3	4	3	6
Aldrin 24 EM	0.85	7	2	3	2	4
Check—Unsprayed	—	2	2	3	3	3

The average fruit infestations in the sprayed and unsprayed plots in relation to the guava crop and to the fly catches in the traps are shown in table 4.

Since there were no host fruits in the experimetnal area for 2 months prior to about June 15, when the guavas began to ripen, all the flies present at that time were believed to be old females which rapidly expended their egg supply. Thus the decline in the total production of larvae to zero after the July 5 spray may not have been entirely the result of the sprays. After July 19 the first progeny of the old flies (June 19 infestation) began to appear and still another generation was produced in September as the summer guava crop declined and the winter crop began to ripen. Obviously most of the flies in the plots in August and September came in from adjacent unsprayed guava areas, since the infestations within the sprayed area in late June, July, and early August were much too low to have produced them.

Fly catches in the unsprayed plots after the third and fourth sprays indicated that the populations had been temporarily checked by the spray applications on nearby plots. During the period from September 6 to October 25 infestations in the six replicates of the unsprayed plot, the five outside supplemental check areas, and in the replicates of the 16 sprayed plots were approximately the same. This was a further indication that the control effected by the sprays had been greater than it was possible to show with the small check replicates adjacent to the treated plots.

RESIDUAL EFFICIENCY OF SPRAYS APPLIED TO GUAVA FOLIAGE.—The results of laboratory studies of the comparative efficiency of the spray residues on guava foliage (table 5) indicated, as in the banana experiments, that dieldrin and aldrin had better residual toxicity than most of the other materials. At the low concentrations tested parathion and lindane were effective immediately after the sprays were applied but they lost practically all their toxicity within 7 days. Both the CS-708 and the aldrin emulsions appeared to be useful only as contact insecticides.

SPRAY RESIDUES.[1]—The average residues on guava fruit 7 days after sprays were applied were 3.3, 4.3, and 1.6 p.p.m. of DDT for 3 treatments in plots where the rate of application was 2.25 pounds of DDT in a 50 per cent wettable powder per acre, 0.20 and 0.34 p.p.m. of parathion where a 25 per cent wettable powder was applied at the rate of 0.85 and 1.70 pounds of toxicant per acre, and 0.31 p.p.m. in plots treated with EPN 25 per cent wettable powder at the rate of 1.4 pounds of toxicant per acre. Good control of the oriental fruit fly on guava without excessive spray residues of these materials on the fruit thus appeared to be entirely possible.

FUMIGATING EFFECTS.—Caged flies were exposed in several of the plots at intervals after treatment to determine if the fumigating effect of parathion noted by Steiner *et al.* (1949) would affect fly mortality. When flies were exposed for 3.5 hours under trees sprayed with the parathion formulation at the rate of 1.70 pounds of toxicant per acre 30 hours earlier, in cages covered on three sides with wire cloth, 100 per cent of them were killed. A comparable exposure to dieldrin killed only 10 per cent of the flies, but when the exposure period was increased to 24 hours all the flies were dead at the end of the period. Lindane and DDT deposits 30 hours old were ineffective as fumigants. The 4-day-old deposits of dieldrin gave 100 per cent kill of the flies during an overnight exposure, aldrin 91 per cent, parathion 26 per cent, and DDT 7 per cent. More than 300 flies were used per test.

When flies were caged in icecream cartons with cheesecloth covers over both ends in the plots sprayed with 0.85 pound of toxicant per acre 2 to 6 hours earlier,

[1] The spray residue analyses were made by Amy Tanada of the Oriental Fruit Fly Project.

89 per cent were killed in 19 hours in the parathion plot, 61 per cent in the lindane plot, and 34 per cent in the dieldrin plot. In 10″ by 10″ by 10″ cages open on only two sides, an overnight exposure of 600 to 900 flies on the day following the applicationf of dieldrin, parathion, and aldrin resulted in 100 per cent kill, whereas in the EPN plot (1.4 pounds per acre) there was 29 per cent mortality. In an unsprayed plot the mortality of flies was only 6 per cent. Parathion caused heavy mortalities of flies caged in unsprayed plants 50 feet downwind from the sprayed plots on the day after treatment. In other experiments where parathion was applied at 0.5 lb. of toxicant per care to the soil only, it killed 100 per cent of the flies caged for 24-hour periods 2 feet above the soil up to 5 days after the application and caused up to 30 per cent mortality in cages 5 feet above ground as late as the seventh day.

In these tests some of the mortality may have resulted from airborne particles of spray residue blown from the foliage, but fumigating action was believed to be largely responsible for the death of the flies.

EFFECTS OF SPRAYS APPLIED TO GUAVA ON ANTS AND LEAFROLLERS.—*Amorbia emigratella* Busck, a leafroller that attacks guava and other vegetation, caused serious damage in all of the dieldrin and aldrin plots. Injury in other plots, including the unsprayed controls, was negligible. Apparently dieldrin and aldrin sprays were not toxic to the leafroller larvae, whereas parathion, EPN, lindane, DDT, and CS-708 prevented the development of this insect. Since no injury developed in the unsprayed plots where ants were abundant, mostly the Argentine ant, and since these ants vigorously attacked, dislodged, or killed leafroller larvae and drove ovipositing moths away, it was concluded that the destruction of ants by the insecticides also contributed to the increase of the leafroller infestation in the dieldrin and aldrin plots.

Seven weeks after the final spray 45 guava bushes or trees in each plot were carefully examined for ants. From 86 to 88 per cent of the guava trees in the unsprayed plots, 84 per cent in the lindane plot, from 40 to 65 per cent in three CS-708 plots, 58 per cent in the EPN plot, 11 and 22 per cent in two parathion plots, from 4 to 24 per cent in four DDT plots, 2 per cent in the plot where aldrin was used at the rate of 1.7 pound per acre, from 35 to 42 per cent in plots where aldrin was used at the rate of 0.85 pound per acre, and 0 and 4 per cent in the two dieldrin plots were found to harbor ants. Exposures of the Argentine ant for 16 hours in cloth-topped jars to foliage samples taken from 5 guava plants in each of several plots 7 weeks after the final spray was applied, indicated that the residues of dieldrin and aldrin wettable powders still had enough residual toxicity to kill from 44 to 90 and from 66 to 100 per cent of the ants, respectively. All other spray materials, including parathion, showed substantial effectiveness. Only 7 per cent of the ants held on unsprayed foliage died in these tests.

Where it is abundant, the Argentine ant explores each guava plant thoroughly. It has been observed to attack and drive oriental fruit fly adults away from the fruit and it destroys many fly larvae and pupae in the soil. The increasing abundance of the Argentine ant undoubtedly has contributed to the declining oriental fruit fly populations in some areas. The destruction of ants by dieldrin and aldrin may be partly responsible for the poor performance of these materials in small-plot field tests despite their excellent residual toxicity to fruit flies; however, current tests indicate that they are mild attractants and may temporarily increase fly oviposition where small plots are sprayed.

EFFECT OF INSECTICIDES ON PARASITIZATION.—The parasitization of oriental fruit fly larvae infesting the bananas was negligible. Parasitization in outlying untreated guava areas averaged 46 per cent, whereas in the untreated test plots it averaged 50 per cent. Parasitization was from 2 to 11 per cent in the five dieldrin and aldrin treatments and from 26 to 69 per cent in plots sprayed with the other insecticides. Dilan emulsifion appeared least toxic. Most of the insecticides permitted less parasitization in the 7-day samples than that which occurred in the unsprayed plots. In samples taken 14 and 21 days after spray applications there was no significant adverse effect on parasitization from the DDT, Dilan, EPN treatments, or from low-concentration applications of parathion and lindane. The chief parasite involved was *Opius*

oophilus Fullaway, whereas *O. longicaudatus* Ashm. constituted up to 3 per cent of the total number of parasites which emerged.

SUMMARY AND CONCLUSIONS.—Preliminary small-plot field tests with some of the new organic insecticides on bananas and guavas in Hawaii have indicated that the oriental fruit fly may be controlled with certain insecticides. The best materials were wettable-powder formulations of parathion applied at rates of 1.7 to 2.2 pounds of toxicant per acre, CS-708 and DDT at rates of 3.4 to 5.2 pounds, and a combination of DDT 50 at 2.25 pounds plus parathion 25 at 0.14 pound. EPN, aldrin, dieldrin, and lindane at rates of 0.85 to 2.2 pounds per acre were also promising when applied to bananas at 2-week and to guava at 3-week intervals. These materials gave average reductions in fruit infestations of 80 to 96 per cent despite a steady influx of flies from contiguous unsprayed areas and a substantial depressing influence of the sprays on fly populations in the unsprayed checks.

At the concentrations used all the materials were highly if not completely effective as space sprays against all oriental fruit flies present at the time of application. In the absence of reinfestation from outside areas, perfect control for 2 or more weeks after a spray should be attainable with them. At the higher concentrations, parathion, EPN, DDT, dieldrin, and aldrin were generally effective as residual sprays for 2 to 3 weeks. Emulsifiable formulations were less effective as residual treatments than the wettable powders.

Parathion, dieldrin, and aldrin applied at rates of 1.7 pounds of toxicant per acre killed flies in cages not touching any sprayed surface for as long as 4 days after an application; EPN and lindane were partially effective. The mortality was chiefly the result of fumigating action, but contact with airborne particles of the insecticides may also have been involved.

Applications of dieldrin and aldrin to guava permitted a serious outbreak of a leafroller, *Amorbia emigratella* Busck, as a result of the comparative non-toxicity of these materials to this pest and their extremely high toxicity to Argentine ants, which contribute extensively to leafroller contol. Although the other materilas, with the exception of lindane, also depressed ant populations, they were toxic to the leaf-roller.

Parasitization of the oriental fruit fly by *Opius* spp. in the plots sprayed with dieldrin and aldrin ranged from 2 to 11 per cent compared with 46 to 50 per cent in unsprayed guava plots. In plots sprayed with other insecticides, parasitization ranged from 26 to 69 per cent. The results indicated that certain of the oriental fruit fly parasites moving in from contiguous unsprayed areas were soon able to parasitize at least as high a percentage of the fruit fly larvae in areas sprayed with 2.25 pounds of DDT or CS-708 per acre, 1.4 pounds of EPN, or 0.85 pound of parathion, as they were in guava stands located outside the treatment area.

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RITCHER TO OREGON

Dr. Paul O. Ritcher, formerly a member of the staff of the Entomology Department in the Kentucky Agricultural Experiment station and, more recently attached to the Department of Entomology in the University of North Carolina, has been appointed to succeed Dr. Don O. Mote as head of the Department at Oregon State College, Corvallis. Dr. Ritcher plans to assume his duties in Oregon on July 1, 1952.

Factors Determining the Effects of Radio-Frequency Electromagnetic Fields on Insects and Materials They Infest[1]

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The diathermic effects of short radio waves are well known to medical men and physiologists, and a great literature has grown up about the subject since the first suggestions for this use were published (Schereschewsky 1926; Hosmer 1928; Christie & Loomis 1929; McLennan & Burton 1931). In recent years also short radio waves have been used for a wide variety of industrial purposes—fabrication of objects made of thermoplastics, production of plywood, cooking of foods—and a sizeable literature is growing up around these (Brown *et al.* 1947; Langton 1949; Cathcart 1946; Morse & Revercomb 1947). The lethal effects of radio waves on insects were reported in some of the earliest papers on diathermic effects (Lutz 1927; Headlee & Burdette 1929). No extended practical uses have come from these studies, however, and many facts about the lethal effects remain rather puzzling.

The most extensive studies on the effects of radio-frequency (RF) electrostatic fields on insects and the materials they infest were made by Headlee and his collaborators (1929, 1931, 1932, 1933, 1934, 1936, 1938; Hadjinicolaou 1931; Pyenson 1933). These workers found that RF electrical fields of sufficient "field strength" were lethal to insects; death was due mainly to general internal heating. Three important factors in RF killing of insects, they reported, were frequency, time, and "field strength" or voltage gradient. The last was defined as the peak difference in voltage between the plates of an air condenser in which specimens were treated divided by the distance between the plates. Headlee and his coworkers further noted that susceptibility to death seemed to be related to the phylogenetic position of the insect, the more highly specialized the insect the more rapidly it was killed. Adults of holometabolous insects also were killed more rapidly than their larvae. These facts suggested that the nervous system, which is most highly centralized in adult Holometabola, was somehow more susceptible to RF heating than other systems. In an attempt to discover the substance in the nervous system which was heating most, they tested a wide variety of materials found in living animals and concluded that cholesterol was eminently possible, because it was found in nervous tissue and heated very rapidly.

If radio waves were to be used to kill insects in or near living plant materials, they should kill the insects without injuring the plants. Accordingly, Headlee and his collaborators treated honey bees, wheat grains and wheat seedlings similarly with a range of frequencies. The higher frequencies (9 to 18 megacycles/second) heated animal and plant tissues similarly. The lower frequencies (1 to 3 Mc./sec.), however, were effective against insects but did not appreciably heat the plant materials. This differential at lower frequencies, they thought, might be used to kill insects in plants without injuring the plants, but no practical tests were made. If soil were present or if the water content of the plant materials were within certain critical ranges, the differential effect disappeared. They believed, however, that insect control with radio waves was practical if infested materials could be heated safely.

A second series of studies was made by McKinley and coworkers (1930, 1931, 1933,[2] 1936). They were not interested in insect control, but with the insects they studied they got the same results as Headlee. They too concluded that death was due mainly to generalized internal heating, except possibly in insects with highly developed nervous systems. The factors they found determining the effects of RF fields on insects were the same as those reported by Headlee's group.

A third group of studies during the

[1] Authorized for publication on January 28, 1952, as paper No. 1717 in the Journal Series of The Pennsylvania Agricultural Experiment Station. This study was financed in part by a grant from the Hawaiian Agricultural Experiment Station and the John Vogel Memorial Research Fund. I am indebted to the following students at this college for their aid in this work: Curtis Williams, Frederick Solomon, William Boyd, Thomas Curry, Richard Herold, and Marion McCrane.

[2] Thesis, University of Pittsburgh.

same years were made by various Russian workers (Vishniakova 1934; Feshott 1935; Evreinov 1935; Andreiev & Balkashin 1935). These workers were mainly interested in control of weevils and mites in stored grains, and they reported much the same results as Headlee's group, so far as the important factors in treatment and death were concerned. Parenthetically, it should be noted that Ark & Parry (1940), in their review article, state voltage gradients for these Russian studies in "volts/cm.^{2}." The Russians themselves, however, use the correct, "volts /cm." These workers claimed that radio waves not only had great practical value in insect control, but also increased the germination of treated seeds.

Some other individuals apparently independent of these three main contributing centers also worked in the field. Davis (1933) and Mouromtseff (1933) reported tests of equipment for the practical control of insects in grain which was stored or in the process of being moved to and from storage. Both reported excellent controls, but the cost of their methods undoubtedly made them impractical economically. Graham & Fabian (1935) reported preliminary studies on the lethal effects of radio waves on insects, and other animals as well. One feature of their report seems difficult to reconcile with other work and indeed with the results of the present study. This is the statement that treatment at 15 Mc./sec. did not kill many of the animals which treatment at 10 Mc./sec. did. This is difficult to understand, because the effectiveness generally increases as the frequency increases. They calculated the voltage gradients, however, and it could be that the two frequencies were not used at the same voltage gradient. No information is given as to the method of calculation, and it is now known that such calculations are hazardous. In general, their work merely shows that radio waves can kill a variety of animals. Kocia (1936), in studies on the effects of radio waves on pupae and larvae, showed that metabolism and developmental rate were increased, probably as a result of increased internal temperatures generated by the radio waves.

The possible use of radio waves for insect control has been reviewed by Ark & Parry (1940). This offers a good summary of earlier work, with the exception noted above, and possibly with the demurrer that they selected for greatest prominence the results of Graham and Fabian (1935) which carry even on the surface a grave inconsistency with other results.

One of the most important contributions to the field was made by Yagi (1938). Unfortunately his paper is in Japanese, and therefore not readily available to most American students. This report was translated for me by Dr. Tokunosuke Watanabe, a visiting research associate in Physics at this college, to whom I am happy to express my thanks. Yagi criticized two points in the previous work, both of them very critical. First, he noted that previous workers had failed to specify what they meant by death in the insects they were treating. He pointed out that immobility and death were not the same, and showed that some insects which seemed dead recovered when removed from the RF field. The "death-point" must thus be clearly specified as "death" or immobilization. Next, he noted the importance of the orientation of the insects in the field. For instance, silkworms with the long axis of the body perpendicular to the plates of the air condenser in which they were being treated were killed rapidly at a relatively low voltage gradient. If the insects were placed parallel to the plates, however, at the same voltage gradient, they would be killed slowly or possibly not killed at all. The same applied to other insects as well, and to wheat grains or heads of wheat. It is interesting to note that this is the first paper in which this important fact was recorded. The failure of the earlier workers to note the orientation of the insects they treated reduces the value of their results.

Recently Webber *et al.* (1946) have evaluated the use of RF fields for insect control in packages. Their work dealt with heating of the packages themselves, and thus, while of considerable value, contributed no information about the killing of insects themselves in RF fields.

The work to date may be summarized as follows. RF electric fields (1 to 50 Mc./sec.) can kill insects; death results mainly from generalized internal heating. The factors which influence the amount of heating are time, average voltage

gradient between the treating plates, frequency, and orientation of the insects in the field. Of these, only the first three have been widely recognized. In insects with complete metamorphosis, adults are killed much more rapidly than larvae, and the more specialized adult insects (flies, bees) are killed more rapidly than the less specialized (cockroaches). This has been theoretically related to the degree of specialization of the nervous system. At higher frequencies, plant and animal tissues heat rapidly and similarly, but at lower frequencies (1 to 3 Mc./sec.) plant tissues do not heat while animal tissues heat fairly rapidly.

The present work was designed to test the possibility that high frequency oscillating electrostatic fields might be used to kill insects inside fruits and vegetables without damaging the plant materials. Specifically, the interest centered about the possibility that eggs and larvae of the Oriental fruit fly, *Dacus dorsalis*, could be destroyed in papayas and other fruits without heating the fruits appreciably. The fact that an RF field penetrates well and thus could reach an insect inside a fruit gave some hope to the effort. The report that lower frequencies have a differential heating effect on plant and animal tissues led to the selection of frequencies of approximately 1, 3, 9, and 27 Mc./sec. for this study. The upper frequency is used in commercial dielectric heating and diathermic devices, the lower frequencies are in the range suggested by Headlee and coworkers as particularly valuable for differential effects.

MATERIALS AND METHODS.—The insects and plant materials were treated between a pair of aluminum plates (15 cm. in diam.) forming an air condenser. This was activated by a commercial RF oscillator[1] with an output rating of 1 kilowatt, modified to give the desired frequencies by the inclusion of extra coils. This had a variable transformer ("Variac") in the power circuit for control of output voltages. No details of this unit are offered here, because measurements of the important variables were all made with devices which did not depend upon the apparatus producing the RF field.

Frequencies were measured with an RF wave-meter (General Radio Type 566A, manufactured by General Radio Co., Cambridge, Mass.). Voltages between the plates were measured with an RF voltmeter[2] reading peak RF voltages. Times were determined with a stop-watch, or by a timer in the primary circuit of the oscillator calibrated against a stop-watch. Internal temperatures (in degrees C.) of insects and fruits were measured with a standard copper-constantan (B. & S. Gauge 30 wire) thermocouple. The thermocouple point was made as small as possible to facilitate insertion into the insects.

The frequencies used in these experiments varied with the distance between the treatment plates and with the materials being treated. Thus, at a setting which gave without the plates in the circuit 27 Mc./sec., the frequencies with plates and materials varied from 24.0 to 27.0 Mc./sec. At a setting which gave without the plates 9 Mc./sec., the actual frequencies were 7.2 to 8.5 Mc./sec. At a setting which gave without the plates 3 Mc./sec., the actual frequencies were 2.5 to 3.0 Mc./sec., and at a setting for 1 Mc./sec., the actual frequencies were 1.0 to 1.1 Mc./sec. These results clearly show the impossibility of calculating frequencies from apparatus "constants," such as the earlier workers used, which disregard the size of and distance between the plates or the materials being treated.

The insects used in these experiments were mostly reared in our laboratory, using standard rearing procedures. A few were field collected. In all 14 species of insects were used, chiefly honey bees, *Apis mellifera*, adult workers, house flies, *Musca domestica* all stages, black blow flies, *Phormia regina*, all stages, milkweed bugs, *Oncopeltus fasciatus* all stages, and American cockroaches, *Periplaneta americana*, all stages.

Various means of confinement during treatment were used. Smaller forms were treated free on the lower plate. More active forms were confined in pyrex test tubes which were pretested to determine that the heating of the tubes themselves was negligible and that they did not shield materials placed inside. Maggots of flies were placed in a small hole drilled in

[1] "Thermatron" Model K 10 S, manufactured by The Radio Receptor Co. of Brooklyn, N. Y.

[2] "Thermex," manufactured by The Girdler Co., Louisville Kentucky.

a thin plate of glass bonded mica[1] to prevent their movements, particularly raising the heads and thus changing their orientation. Many plant materials were also tested, including papaya, banana, apple, potato, carrot, squash and white pine blocks. All the objects were treated at or near the center of the field and were of such dimensions that they were not near the edges of the plates.

EXPERIMENTS.—*The Time Factor.* Under otherwise identical conditions, heating of an object in an RF field should be directly proportional to time of treatment. This proved to be the case, except that with long times of treatment or when materials reached relatively high temperatures loss of heat to the surroundings was a factor.

In determining death-times in insects, the same problem was encountered that Yagi (1938) noted. Previous work on death-times could not be duplicated. This led to an examination of earlier reports to find the criteria of death used by these workers. Unfortunately, none were given. For the honey bee or the house fly there are two or three stages in death which might logically be called "death." When the field is turned on, if of sufficient voltage gradient, the bee or fly is knocked down onto its dorsal side. Following this the insect buzzes about on its back for a time. When this wing movement has stopped, the animal lies in one place moving the body agitatedly. Finally, when this movement is suspended the proboscis is extended stiffly and the animal is rigid. It is quite obvious that internal heating is the final cause of death in this sequence, for a large quantity of water vapor is cooked out of the fly or bee during the last stages. At 25 Mc./sec. and high voltage gradients, all these may occur in 5 to 10 seconds. At lower voltage gradients, they are more extended in time with the knock-down occurring almost immediately, but proboscis extension delayed for 2 or 3 minutes. It is vital, therefore, that the criterion of "death" be specified exactly. Possibly the word, "death," should be avoided. It is useful only because it is short. But it must be carefully defined for each species of insect, because all insects do not necessarily show the same pattern. The cockroach, for instance, "dies" in a different series of stages than the fly.

The Voltage Gradient Factor. The average voltage gradient is the difference in voltage between the plates of the air condenser in which the object is treated divided by the plate separation. Obviously the voltage difference is oscillating millions of times per second, so that the average voltage difference is zero. The voltages reported herein are the peak RF voltages achieved in each cycle.

The results at different average voltage gradients with *Phormia regina* and *Musca domestica* adults, expressed as "killing time" (till final extension of the proboscis and rigidity) and with white pine blocks and potato slices expressed as temperature change are shown in figure 4. These are characteristic of the results with the other insects and slices of various other fruits and vegetables. Obviously the effectiveness as a heating and killing agent increases with increasing voltage gradient. Theoretically the heating should be proportional to the square of the voltage gradient (Langton 1949), and that is approximated by these results.

The Vertical Fraction Factor. The average voltage gradient can be altered in two ways: 1, the voltage itself can be changed with the plate separation constant by using a rheostat in the primary circuit of the oscillator, or 2, the distance between the plates can be changed with the voltage constant. In our earlier work we used the latter method, because this is simpler and earlier workers had not given the plate separations they used. The fallacy of this procedure became obvious, however, during the testing of papaya slices and maggots to determine the relative heating rates. With the same frequency and voltage gradient across the plates, the papaya slices (1–2 cm. thick) were heating rather rapidly while the maggots were heating rather slowly. Obviously it was not correct to compare the thick papaya slices with the thin maggots. Accordingly, the vertical fraction of the field occupied by the papaya was changed while the voltage gradient across the plates remained constant to get data for the plotting of a curve which migh be extrapolated to the dimensions of the maggot to allow comparison. This curve—heating vs. fraction of field occupied (in per cent)—is shown

[1] Mykroy.

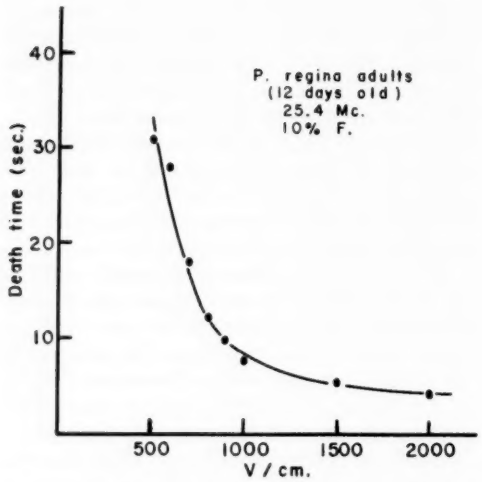

FIG. 1.—The time of treatment in seconds in an RF field (25.4 Mc./sec.) needed to kill *Phormia regina* adults as a function of the average voltage gradient between the treatment plates. The flies occupied 10 per cent of the field vertically.

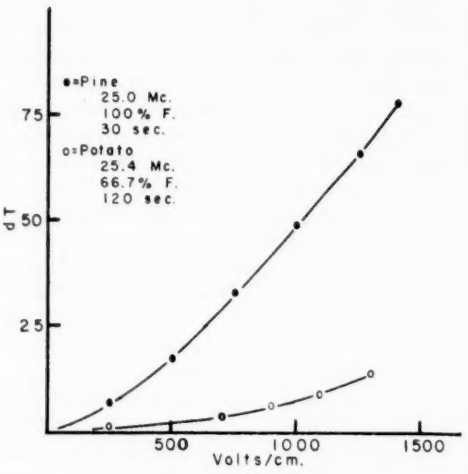

FIG. 3.—The temperature rise (dT) of white pine blocks and potato slices in an RF field at the frequencies, times of treatment and per cent of field occupied vertically noted on the graph, as a function of the average voltage gradient between the treatment plates.

in figure 4. There is obviously a profound effect when the vertical fraction of the field occupied by the treated sample is changed.

This led to a further study of this factor and a review of the literature to determine whether the inability to duplicate earlier results with respect to killing times might not have been due to this. With the exception of the work by Yagi (1938), none of the earlier workers seems to have thought enough of this factor to bother to report plate separations or thicknesses of insects or other samples. Without these data, duplication is impossible.

Figure 4 shows the effect of varying the vertical fraction of the field on the heating of both papaya and white pine blocks. Fig. 5 shows the effect of varying the percentage of the field occupied vertically on death time (till terminal proboscis extension) in *Oncopeltus fasciatus*. These are samples of data obtained with other insects and plant materials as well.

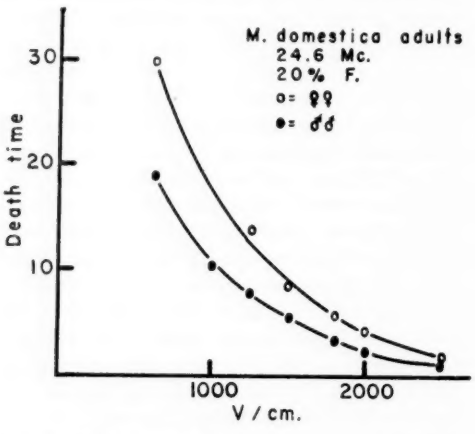

FIG. 2.—The time of treatment in seconds in an RF field (24.6 Mc./sec.) needed to kill *Musca domestica* adults (o=females; • =males) as a function of the average voltage gradient between the treatment plates. The flies occupied 20 per cent of the field vertically.

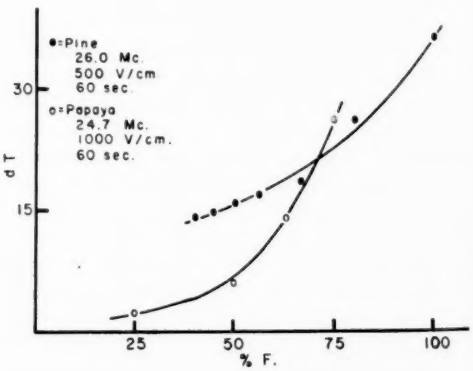

FIG. 4.—The temperature rise (dT) in white pine blocks and papaya slices under the conditions given on the graph as a function of the vertical fraction (in per cent) of the RF field occupied by the treated objects.

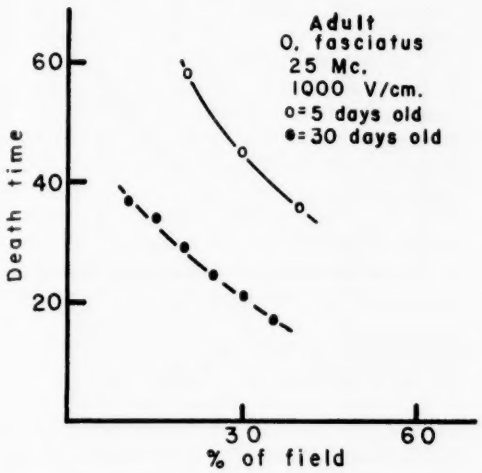

FIG. 5.—The time of treatment in seconds in an RF field (25 Mc./sec.) needed to kill *Oncopeltus fasciatus* adults at an average voltage gradient of 1000 V/cm. as a function of the vertical fraction (in per cent) of the RF field occupied by the bugs.

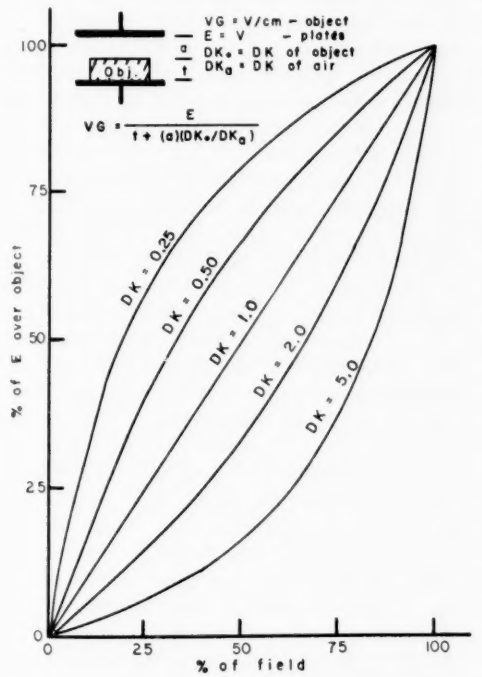

FIG. 6.—Theoretical voltage gradients across objects (Obj.) of various dielectric constants (DK's given on curves) when placed in an RF field which includes an air gap as a function of the per cent of the field vertically occupied by the objects ($t/a+t \times 100$). The equation for the voltage gradient across the object (VG) is given: E = voltage between the plates; t = thickness of the treated object; a = thickness of the air gap; DK_o = dielectric constant of the treated object; DK_a = dielectric constant of air (= 1).

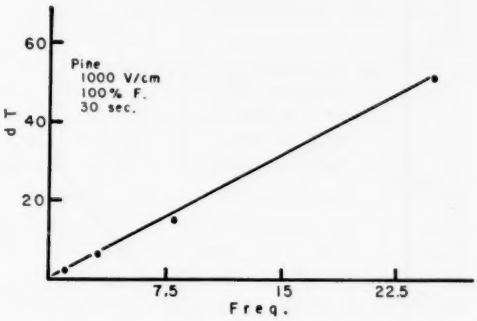

FIG. 7.—The temperature rise (dT) of white pine blocks in an RF field, under the conditions given on the graph, as a function of frequency of the electrostatic oscillations.

The importance of this factor is quite simple to explain. The voltage gradient across the plates is not the determining factor in a situation in which an air gap is present. The voltage gradient across the treated specimen is the determining factor. Obviously, if the specimen touches both plates, the full voltage gradient is across it. If it occupies only 50 per cent of the vertical field, however, the fraction of the voltage gradient across it is determined by the ratio of the dielectric constants of it and of air. Fig. 6 shows the theoretical effective voltage gradients across objects with different dielectric constants with an air gap present, as a function of per cent, of the field occupied vertically. The equation which gives the effective voltage gradient across the object between the plates with an air gap present is also given (Langton 1949).

Yagi's results, therefore, fall within the framework of this more general principle. A worm held parallel to the plates occupies, let us say, 10 per cent of the field vertically, but held perpendicular to the plates might occupy 80 per cent of the field. Small wonder that it is unharmed or heats slowly in the first case while it may be destroyed rapidly in the second.

With these facts in mind, it is obvious that, if one desires to compare one insect with another, it is necessary to measure the thickness of each individual to be tested before setting the plate separation, and then to adjust the voltage applied to the plates to give the correct average voltage gradient. Thus, if we were to compare a cockroach with a maggot, the thickness of each must be measured, each must be made to occupy a given fraction

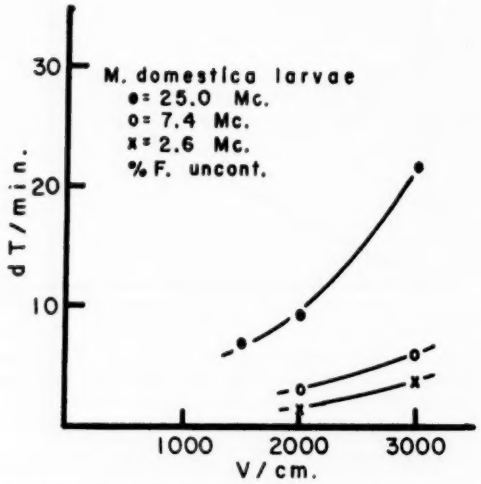

FIG. 8.—The temperature rise (dt/min.) of *Musca domestica* larvae in an RF field at the frequencies given on the graph as a function of the average voltage gradient between the plates. The vertical fraction of the field occupied by the treated insects varied with the average voltage gradient.

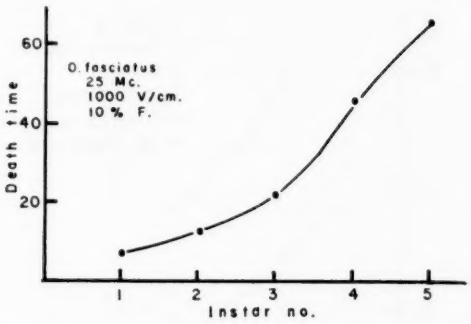

FIG. 9.—The time of treatment in an RF field, under the conditions specified on the graph, needed to kill *Oncopeltus fasciatus* nymphs and adults.

of the field vertically (and care must be taken to see that the orientation does not change during treatment), and the applied voltage must give the same average voltage gradient between the plates. Only thus can two species or individuals be compared. Even then, the effective voltage gradient across the two is the same only if both have the same dielectric constant—an unlikely situation. Comparisons of heating rates are thus difficult or impossible to interpret, because the differences may result from differences in dielectric constants, in other electrical or biological properties, or in some combination thereof.

Some of the earlier workers have reported killing insects in grain samples without heating the samples to the lethal temperature for the insects. They believed this to be due to specific biological effects of the RF field. The vertical fraction factor alone may account for the fact that some killing of insects infesting grains is obtained, even though the over-all temperature of the grain samples is not brought to the thermal death point of the insect. Those grains which were vertical in the long axis could be heated to the thermal death point, but the grains which were horizontal need not be. The average temperature would fall short of that needed for killing, but the kill would still be due to heating of individual grains containing insects. For that matter, if the grains were passing through charged plates, the grains might all be heated at some time during the passage to the thermal death point of the infesting insect, even though the over-all temperature would never achieve the necessary value. One cannot, therefore, assume from a measurement of general temperature in a mass of treated grains that insects are killed other than by heating unless he shows that the individual grains are all heated similarly.

The Frequency Factor. This factor was the most intriguing to previous workers. The hope, of course, was to find some frequency which would heat insects—or in medical work some special tissue—without heating infested materials or other tissues. No attempt will be made here to review the medical literature. Suffice it to say, however, that there seems to be no special diathermic frequency. Heating effectiveness increases as the frequency increases. From a theoretical standpoint, this is exactly what one would expect. In the case of pure compounds there are resonant frequencies at which absorption and heating are greatest. But with heterogeneous materials, such as biological objects, so many compounds are present that the individual resonant points are masked and heating effectiveness increases regularly with frequency. At very high frequencies, the so-called "skin effect" (tendency of the current to pass over the surface) and increased reflection from the surface reduce penetration to too low a point to produce any internal heating.

Figure 7 shows the heating of white

pine blocks at different frequencies. Obviously there is a direct relationship here, the higher the frequency the greater the heating. Experiments with papaya, potato, and other vegetable samples occupying at different frequencies the same vertical fraction of the field with the same average voltage gradient between the plates showed exactly the same effect. Fig. 8 shows the same experiment with *Musca domestica* larvae. At 1 Mc./sec. there was no appreciable heating. With honey bees, the experimental animal of Headlee and coworkers, the results were duplicated, and the other insects yielded similar results. So far as could be determined, there are no differences in the heating of insects and plant materials at different frequencies—the lower the frequency the less the heating and the less effective the field as an insect-killer.

The question now arises as to the reasons for the discrepancy between these results and those of Headlee and his coworkers. First of all it should be noted that we measured actual internal temperature rise, or called death the final proboscis extension. It is interesting to note that the various stages in death are not uniformly affected by changing frequencies. Thus the knockdown that occurs so dramatically at the turning on of the current with flies and bees, remains even at 3 Mc./sec., though much slower, but the insects cannot be killed in the field in any reasonable time. Since "death" is not defined by the earlier workers it is impossible to judge whether this is the reason or not. Secondly, the effect of vertical fraction of field occupied seems to have been missed by Headlee and his collaborators. Thus comparing a honey bee adult with a blade of seedling wheat, the bee probably 30 times as thick, or even with a wheat seed, the bee possibly 10 times as thick, is not possible without adjustment to standard conditions.

Armed with the information obtained thus far, it is easy to answer the question originally asked regarding the possibility of using radio waves to kill maggots inside papayas. Obviously the answer is in the negative. In the first place, there seems to be no really critical differential in heating at different frequencies. The most efficient working conditions would therefore utilize the highest frequency consistent with the increasing cost of producing higher frequencies and with increasing loss of penetrability. In this case, the effective voltage gradient across the papaya would be many times that across the maggot inside, because it would occupy so much larger a fraction of the field vertically. Only a truly remarkable difference in dielectric constant between the two could overcome this, and that apparently does not exist, because both maggots and fruit heat similarly. This method for killing maggots in fruits could be used, therefore, only if the fruits were not injured by heating to the lethal temperature of the maggot. This temperature could be achieved uniformly throughout the fruit in a very short time instead of from the outside in, as in conventional heating methods. Some advantage is achieved, but not enough for practical purposes.

The Physiological Factors. With the knowledge obtained to this point, it seemed of interest to test numerous species of insects for the effectiveness of radio destruction, with the hope that some comparison of their heating rates under comparable conditions would give insight into the nature of the chemical or physical factors determining the heating rate. Accordingly, a number of species were tested as brought in from the field. These were all treated at 25 Mc./sec. and 1000 volts/cm., while they occupied 10% of the field vertically.

The most important result was the large variation in death times for insects even of the same species. Thus death times for spider beetles ranged from 1 minute to 3 minutes, for tarnished plant bugs from 6 to 9 seconds, for grasshoppers, *Melanoplus femur-rubrum* from 6 to 8 minutes. Since, in each case, a standard end-point for "death" was selected, this was not the result of shifting aspects of "death." We already had found that the sex of house flies influences the death-time (Fig. 2). But the sex was not the only factor. To study the possible effects of age on the effectiveness of RF fields on insects, laboratory reared *Oncopeltus fasciatus* were treated at different instars under fully standard conditions. The results are shown in figure 9.

There is a tenfold increase in "resistance to death" in an RF field from the first to the fifth instars in this insect. Still more interesting is the effect of the age of

adults on resistance. Fig. 5 presents data for adults of two different ages. The young adults required about twice as long to kill as the older bugs under comparable conditions. There are many possible reasons for this. The differences could be differences in electrical properties resulting from changing body composition, or they could be differences in heat death temperatures. The latter seems unlikely, for preliminary determinations of heat death temperatures of old and young adults indicated no great difference between them. Further work is needed to elucidate the nature of the differences.

Even with standardization of treatment conditions, therefore, comparisons between two species of insects can mean little, unless extensive tests are made at different ages and physiological states. Thus, to compare a cockroach with a fly, it would be necessary not only to maintain standard frequency, voltage gradient and vertical fraction of the field occupied, but also to know the exact physiological state, age and sex, and the effects of each of these in each species. At this point, one is well advised to ask what a comparable physiological condition and age would mean when applied to two species so different as the cockroach and the fly. It is obvious that interspecies comparisons, therefore, can yield little of value with the present state of knowledge, and intraspecific comparisons must be made with full respect for the imponderables involved.

The Morphological Factor—One of the early discoveries about the effects of RF fields on insects was the differences in susceptibility between the adults and the larvae or pupae of holometabolous insects. The adults were knocked down dramatically and killed rather rapidly, while the larvae or pupae were killed much more slowly and without any sudden knock-down. This was supposed to be due to the fact that the nervous system, which was most "centralized" in the adult, was more susceptible to RF heating. This idea was supported by the observation that hemimetabolous insects did not show any sharp break in susceptibility between nymph and adult and as adults required longer in general to kill than adults of the holometabolous groups. Our experiments confirmed this, in a general way, though, as has already been pointed out, little or no trust can be put in generalizations drawn from interspecific comparisons. It should be noted, however, that the hemimetabolous milkweed bugs and tarnished plant bugs are knocked down and killed like bees and flies rather than like the other hemimetabolous insects tested. Nevertheless, a striking difference between the larva or pupa and the adult of house flies and blow flies remains.

It would be fruitless to discuss whether or not the nervous system of the adult in these cases is actually more "developed" or "centralized," though one is inclined to question this conclusion. The explanation, when found, proved to be somewhat simpler.

Hosmer (1928), studying the heating of simple salt solutions in RF fields, noted that the shape of the containing vessel had interesting effects. If the vessel had a side-arm which was located in the middle vertically between the plates, the contained fluid heated uniformly. But, if the side-arm were located at the bottom or the top of the vessel, the solution in the side-arm would boil almost as soon as the current was turned on, before the main body of solution in the vessel was heated appreciably. Her conclusions are very significant, for in these probably lies the answer to the problem. She wrote, "Marked heating occurs whenever there are attenuated conducting paths, particularly if these run perpendicularly to the plates or are connected asymmetrically to similar paths which run perpendicular to the plates. In the latter case, the action is that of an antenna collecting charge from the parallel plate and conducting it to the perpendicular path." A moment's reflection will show that an adult fly meets these requirements exactly. The legs are attached asymmetrically to the main bulk, and they should therefore act like the side-arms in Hosmer's experiments. The fluid in them should boil almost as soon as the field is turned on, causing the sharp jerk that gives the knock-down. The attachment of the legs to the body-wall near the ventral nerve-cord probably accounts for the severe nervous spasm and paralysis that follow. If the current is turned on for only a second, treated flies may live for some time, but they do not regain the use of their legs.

Two tests of this hypothesis were made. First, house flies with the legs and wings removed were tested in the apparatus. These occupied 10% of the field vertically, at an average voltage gradient of 1000 volts/cm. and a frequency of 25 Mc./sec. Normal flies were knocked down in less than 1 sec. and extended the proboscis rigidly in an average of 9 sec. Wingless flies reacted in essentially the same manner. Legless flies, on the other hand, showed no evidences of knock-down and were not dead until 23 sec. Naturally, one could not expect a true knock-down without legs, but there was no evidence at all of the generalized spasm that occurred as the current was turned on in flies with legs. Flies lacking both wings and legs reacted similarly to those with only legs removed. This would indicate that the wings are not involved in the knock-down. One may ask why they are not, since they meet the requirements for "attenuated conducting paths."

The second experiment answered this question. A study was made of the heating of white pine blocks in which holes were drilled to receive dowels. With "dry" blocks (2 cm. thick), tests were made at a plate separation of 7 cm., a treatment time of 30 sec., a voltage gradient of 350 volts/cm. and a frequency of 26 Mc./sec. The blocks without dowels heated an average of 12° C. With "dry" dowels (2.5 cm. long) inserted, and so placed that the long axis of the dowels was perpendicular to the plates, the blocks heated as before, but the dowels heated 20° C. The blocks and dowels were then soaked in tap-water. In this case, the blocks alone heated 20° C. When the moist dowels were added, however, they started to give off steam within 1 sec. after the current was turned on, and heated 40° C. within 10 sec. In fact, the almost immediate boiling of water from the dowel looked just like the almost immediate effect of the RF field on a fly. Further, the point of contact between the dowel and block was heated most markedly, reaching 100° C. in a few seconds. The difference in results between the "dry" and moist dowels shows the reason for the difference in reaction between wings and legs as collectors and conductors of electricity. The wings are relatively dry, while the legs are actually tiny side-arms containing salt solution.

There is a good reason, therefore, why insect nymphs and adults do not differ sharply in reaction to RF fields while larvae and adults do. We may further note that a possible reason for the rapid killing of first instar milkweed bugs noted earlier might be due to the fact that the legs are longer in proportion in this stage than in later stages. Much further exploration of leg structure and leg attachment in different orders would be necessary before one could say unequivocally that the differences among the orders are due to morphology alone, but certainly any theoretical explanation for these differences must take this into account. Without a clear-cut rationale at this time to relate shape and internal composition to electrical reactions, it is difficult to see how any valid comparisons between species on a basic level can be made. This factor, the most important of all in many ways, has been missed by all previous workers with insects in RF fields. Combined with their neglecting to record the fraction of the field occupied by the treated materials, this makes their work of qualitative value only.

Some earlier students (McKinley 1930, 1933[1]; Bucher 1941) also reported necrosis of the tails and legs of mice following exposures to RF fields, believing these to be specific biological effects. They too are undoubtedly the result of the geometry of the treated objects. In fact, many of the "biological effects independent of heat" recorded by earlier workers are probably biological only in an anatomical sense. Heat—local to be sure—is still involved.

It might also be noted that the attenuation of conducting paths and the presence of interfaces on the microscopic level has an effect. Marshall (1930) has shown that the degree of emulsification of biological solutions affects the heating rate. One could imagine further that cell boundaries and tissue interfaces might also have an influence. Until the effects on RF heating of all these morphological factors are studied, comparisons even between two individuals of the same species otherwise under standard conditions must be made cautiously.

DISCUSSION.—The earlier reports that insects can be killed and infested material

[1] Thesis, University of Pittsburgh.

can be heated dielectrically in a high intensity, high frequency (3–25 Mc./sec.) electrostatic field are confirmed by this study. The lethal effects of RF fields would seem to be almost entirely due to the internal heating of the insects. This may be general, or it may be localized as a result of the shape or physiological state of a part of the body.

The important variables in the treated materials or insects which require specification, if results are to be duplicated, are the following:

1. The age, sex and physiological state of the organisms must be controlled or at least specified as far as possible. Except for mere qualitative comparisons, for instance, field collected specimens are next to useless.

2. Whenever the criterion of effectiveness is death, this must be clearly defined. Insects die in stages, so to speak, and these vary with the species. In fact, as Yagi (1938) stated, it is probably impossible to determine a death-point externally in insects. Therefore, the end-point selected must be clearly specified. Better yet, internal temperatures should be determined, for these are easy to measure with a thermocouple and from them one can find the time necessary to kill, if the thermal death point of the insect is known.

3. Most important of all, however, the shape of the insects, particularly the presence or absence of appendages, and the shapes of other materials must be considered. The differences in death-times of an adult fly and of a maggot are probably mainly the result of the changed shape. Comparisons between different species on a basic physical level are not possible, because of the different shapes. Further, the thickness and shape of treated materials of any kind, especially with reference to the vertical distance between the plates must be specified. This may require, if comparisons are desired between different samples of a given fruit, that slices be made with extreme care.

The important variables in apparatus and methods of treatment which must be controlled or specified, if results are to be duplicatable, are the following: 1. time of treatment; 2. frequency of the radio waves; 3. voltage applied to the treatment plates; 4. distance between the plates; and 5. dimensions of the treated object, particularly the thickness with respect to the vertical distance between the plates provided that the object is not large enough to extend near to the edges of the treatment plates.

The last three items may be variously combined. They are probably easiest to express as average voltage gradient (voltage across the plates/plate separation) and vertical fraction of the field (thickness of treated object/plate separation). The latter may, of course, be converted into per cent, if desired. Thus at least four parameters should be given: time, frequency, voltage gradient, and vertical fraction of field; with these figures it is possible to duplicate the conditions of treatment.

Much remains to be done before any rational approach to the basic problems of RF heating of insects and fruits will be possible. Studies should be made of the relationship of heating to water content and distribution of water in the treated materials. Changes in electrical properties during ageing or after cutting of fruits and vegetables would be of interest. If materials were selected that could have the shape controlled, as is impossible with insects, perhaps data could be obtained on the effects of cellular organization on heating and perhaps correlations between chemical constituents and heating could be fruitfully made. This would allow prediction of the relative heating rates of insects and the materials they infest. In the meantime, every problem must be approached through specific experiments.

Dielectric heating is expensive heating and only justified in special cases, where its penetrating power can be used to advantage. It will be noticed that wood samples heat very rapidly in an RF field. Through the courtesy of the U. S. Department of Agriculture's Forest Insect Division we received wood samples infested with powder post beetles for RF treatment. It was quite simple to kill the insects rapidly by heating the wood in the RF field. Sufficiently high temperatures (75° to 90° C.) were achieved in sap-wood in 15 to 30 sec. Possibly RF heating may offer a solution to some of the problems of insect control in wooden structures. For instance, if a beetle infestation were present in a beam of a house, it would be possible to create local fields serially

along the length of the beam, without disturbing the existing structures and thus heating it enough to kill the insects in all stages inside. This could be done by grounding the radio generator, placing a long strip of grounded metal down the outside of the beam and moving a small plate slowly along the inside. The same possibility exists for furniture infested with wood-boring beetles. Certain packaging problems might be solved also with RF treatments, the possibility determined mostly by comparative costs.

With respect to the problem which originally started this investigation, it seems that fruits could not safely be "sterilized" by this means, except in cases where the thermal death-point of the infesting insect is very low. However, some possibilities still remain. Further work should be done on the comparative electrical properties of rind and pulp of papaya. If these had certain values, the major part of the current would go through the rind. Since the maggot of the fruit fly is in the rind, this would put it in a region of high current density and could result in death. Second, increased frequency could give sufficient "skin effect" to result in little or no heating in the pulp, but a high current density through the rind. Both possibilities seem worthy of investigation, but must be tested with the species involved. It no longer seems advisable to study house fly and *Drosophila* maggots in the belief that we learn what we need to know about other species. The study of practical utilization of RF fields in insect control remains chiefly empirical.

SUMMARY.—Fruits and vegetables are heated and insects are killed when placed in radio-frequency (3–27 Mc./sec.) electrostatic fields. The main cause of death in insects is dielectric heating which may be general or localized. The rate of heating of treated objects is determined by the frequency and average voltage gradient of the RF field, the vertical fraction of the field occupied by the treated object if an air space is present, the chemical and physical state of the object (in insects this may be a reflection of age, sex, or physiological condition) and the shape of the object. The last is of special importance is insects with appendages: the legs may act as conducting paths which heat strongly long before any generalized heating occurs. This probably accounts for the fact that adult insects with complete metamorphosis are knocked down almost immediately and killed very rapidly by an RF field, while the larvae are not knocked down and are killed much more slowly. No critical differential in heating at various frequencies between plant and animal tissues was found. It is probably impossible to heat an insect inside a fruit or vegetable without heating the plant material also.

If results of experiments with RF fields in insect control are to be duplicatable, the following information must be given about the treated materials: size and shape, age, sex and physiological state of treated insects, and exact "death-point" of the insect used or better yet the actual change in temperature. The following information about the treatment conditions must also be given: time of treatment, frequency and average voltage gradient of the RF field, and if an airgap is present the vertical fraction of the field occupied by the object. In the present state of knowledge, the study of possible practical utilization of RF fields for insect control remains chiefly empirical.

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TWENTY-SIXTH ANNUAL WESTERN COOPERATIVE SPRAY PROJECT CONFERENCE

The Twenty-Sixth Annual Conference of the Western Cooperative Spray Project was held at Portland, Oregon, January 23 to 25, 1952, for a discussion of research work being done by the members on pest problems of deciduous fruit trees. Of paramount interest were the reports on the development of acaricides. Research on such fruit insects as aphids, scale, pear psylla, cherry fruit fly, codling moth and insects attacking cranberries was also reported on. Tree fruit diseases such as mildew, scab and fire blight were discussed.

A resolution was passed to urge the establishment of a cooperative research project in the Western Region on a study on insecticide dispersal equipment. On the last day the members met jointly with the Western Agricultural Chemical Association at a luncheon. There were 71 registered for the closed sessions and 128 at the open meeting. Mr. E. J. Newcomer, Past Chairman and Mr. Fred L. Overley, Past Secretary, were given a special vote of thanks for their very valuable service to the organization since its inception in 1926.

H. S. TELFORD, *Chairman*
JAMES MARSHALL, *Co-chairman*
LOUIS G. GENTNER, *Secretary*
HAROLD F. MADSEN, *Assistant Secretary*

Effect of Environmental Factors on the Toxicity of Certain Insecticides[1]

J. C. Gaines and W. J. Mistric Jr., *Texas Agricultural Experiment Station, College Station*

Investigations have been continued at this station relative to the environmental factors affecting the toxicity of certain insecticides. Results of work conducted during the period 1948 to 1950 have been reported by Gaines & Dean (1949, 1950) and Gaines & Mistric (1951). High temperatures and humidities, rainfall, sunshine and dew proved to be important factors in reducing the toxicity of organic insecticides. The emulsion sprays seemed to remain more toxic under certain conditions than the dust formulations. Results of tests reported in the papers cited above and by Rainwater & Gaines (1951) indicated that factors other than environmental greatly affected the toxicity of certain insecticides. Boll weevils were more susceptible to poisons during the early growing season than they were during the latter part of the summer and early fall.

The tests herein reported were conducted at College Station during 1951 for the purpose of obtaining additional information regarding the effect of sunshine, dew and rain on the toxicity of certain insecticides.

The following new compounds were included in tests this year: (1) TM-269, a stereoisomer of dieldrin, TM-711, a stereoisomer of aldrin, TM-4049, S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate, and TM-1, Goodrich experimental compound containing a mixture of chlorinated terpene isomers and EPN, ethyl p-nitrophenyl benzene thionophosphonate. The toxicity of these new materials as well as toxaphene, dieldrin, aldrin, parathion and gamma benzene hexachloride-DDT mixture were compared in tests against several insects.

The boll weevil, *Anthonomus grandis* Boh., the cotton leafworm, *Alabama argillacea* (Hbn.), the garden webworm, *Loxostege similalis* (Guen.), and the saltmarsh caterpillar, *Estigmene acrea* (Drury), were used as test insects.

The methods used in making these tests have been described in the papers referred to above. The percentages of mortality were calculated by Abbott's formula and the dosage-mortality curves were calculated by Bliss' method. The dosages are shown as pounds active ingredients per acre. Check or untreated insects were included in all tests. The sprays were made by diluting miscible oil concentrates with water.

In the laboratory tests, the sprays were applied to potted cotton plants. Two hollow cone nozzles were used for dispensing the spray at the rate of approximately 5 gallons per acre. As described in previous papers, the plants were rotated through the spray. In the field cage tests, the sprays were applied to individual plants enclosed in a clyinder. A solid cone nozzle dispensing about 7.5 gallons of spray per acre was used. All sprays were applied at low pressures. The number of live and dead insects were recorded at the end of a 5-day test period. In the cases where the insects were released immediately following treatment, the test period was 5 days while in the case of 24 hour delay, the period was 6 days.

The percentage mortality shown for each dosage in the laboratory tests represents the average for four replicate cages using from 10 to 15 worms or weevils per cage. In the field cage tests, the percentage mortality shown for each dosage represents the average of four replicate cages using about 25 weevils per cage.

Experiment 1 shown in table 1, was conducted to compare the dosage of toxaphene spray required to kill comparable percentages of overwintered weevils, weevils reared from infested squares and weevils collected from the field. A comparatively low dosage of toxaphene was required to kill overwintered weevils early in June. A few weeks later, it required nearly 3 times the dosage to kill a comparable percentage of weevils reared from the squares. Apparently, the depletion of food in the overwintered weevils affected their resistance to insecticides. A still higher

[1] Technical contribution No. 1560, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due M. E. Merkl and F. M. Fuller for assistance in conducting some of the tests.

dosage of toxaphene was required to kill a comparable percentage of hardy field collected weevils in October. Due to excessively dry weather the majority of field collected weevils emerged from squares rather than bolls. In previous years, the majority of the fall bred weevils emerged from infested bolls and have proved even more difficult to kill with normal dosages of any insecticide.

Experiment 2 shown in table 2, was conducted in the laboratory to compare the dosages of toxaphene spray required to kill comparable percentages of weevils reared from squares and from bolls. It required about 4 times more toxaphene to kill weevils reared from bolls than those reared from squares. These data again indicate that the food upon which weevils developed greatly affected their resistance to toxaphene. It will also be noted that it required much higher dosages of toxaphene to kill comparable populations of weevils in the field than in the laboratory. The higher temperatures, wide range in relative humidity, sunshine, dew or combination of these factors are important in reducing the toxicity of toxaphene spray.

Cage tests in experiments 3 and 4 were conducted in the laboratory and field, respectively. In both experiments the toxicities of dieldrin, aldrin, TM-269 and EPN were compared to that of toxaphene. In one series of tests in the laboratory experiment, table 3, the boll weevils were released immediately after the plants were treated and they remained under laboratory conditions. In another series, the weevils were released 24 hours after the plants were treated. During the 24-hour period, the plants were stored in the laboratory. In the third series, the weevils were released 24 hours after the plants were treated. During this 24-hour delay period, the plants were stored outside exposed to normal environmental conditions. The maximum temperatures on the days the plants were exposed to outside conditions, were 100° and 104° F. as compared to the average maximum temperature in the laboratory during the test periods of 95.5° F. The toxicities of all the insecticides except aldrin were little affected by the 24 hour delay in releasing the weevils when the treated plants were stored in the laboratory in the shade at about 95.5° F. This was not the case when the plants were subjected to outside environment during the 24 hour delay period. Sunshine, wide range in relative humidity and high temperature were important factors in reducing the toxicity of all the insecticides used. The toxicities of toxaphene, dieldrin and EPN were reduced less than either TM-269 or aldrin.

In one series of tests in the field cage experiment 4, table 4, the boll weevils were released immediately after the plants were treated. In the other series, the weevils were released 24 hours after the plants had been sprayed. All plants were outside, exposed to normal environmental conditions. Under normal conditions dieldrin and EPN lost little of their toxicity as a result of a 24-hour delay in releasing the weevils. As in the laboratory experiment 3, the toxicity of EPN and dieldrin was reduced less than any of the other materials used. As indicated in the footnote, table 4, the maximum temperature during the delay period ranged from 100° to 106° F. and the average maximum temperatures during the test periods ranged from 102.8° to 105.7° F. It will be noticed that much higher dosages of all insecticides were required to give kills in the field comparable to those obtained in the laboratory. These tests again indicate that such factors as high temperature, sunshine and wide ranges in the relative humidity reduced the toxicity of all the organic insecticides.

Cage tests in experiments 5 and 6 were conducted in the laboratory and field respectively. In experiment 5, the toxicities of TM-1, TM-711, TM-4049 and parathion were compared to that of toxaphene. In one series of tests conducted in the laboratory, table 5, the boll weevils were released immediately after the plants were sprayed and they remained under laboratory conditions. In the other series the weevils were released 24 hours after the plants were treated. During this 24-hour delay period the plants were stored outside, under normal environmental conditions. The maximum temperatures on the days the plants were exposed to outside conditions ranged from 84° to 107° F. as compared to the average maximum temperature of 85° in the laboratory during the test periods. The toxicity of the phosphorus com-

Table 1.—The mortality of boll weevils as indicated following treatments of toxaphene spray in field cage tests in experiment 1 at College Station, Texas.

Date	Dosage	Source of Weevils	No. of Replicates	Total No. Weevils	Per Cent Mortality
6/7	1.5	Overwintered[1]	4	71	75.0
7/5	4.0	Squares[2]	4	88	78.1
8/21	4.0	Field dollected[3]	4	94	61.3
10/4	6.0	Field collected[3]	6	132	72.9

[1] Overwintered adult weevils collected from cotton fields.
[2] Weevils reared from field collected punctured squares.
[3] Weevils collected from infested fields.

Table 2.—The mortality of boll weevils as indicated following treatment of toxaphene spray in the laboratory in experiment 2 at College Station, Texas.

Dosage	Source of Weevils	No. Replicate Cages	Total No. Weevils	Per Cent Mortality
.12	Squares[1]	24	246	73.8
.50	Bolls[2]	30	266	83.5
.50	Field[3]	30	287	82.6

[1] Weevils reared from field collected punctured squares.
[2] Weevils reared from field collected infested bolls.
[3] Weevils collected from infested fields.

pounds and TM-711 was greatly reduced in the 24 hours. The toxicity of the chlorinated terpene compounds, toxaphene and TM-1 was not reduced appreciably in 24 hours under these conditions. Apparently such factors as sunshine, dew and percentage relative humidity greatly reduced the toxicity of parathion, TM-4049 and TM-711.

In one series of tests in the field cage experiment 6, table 6, the weevils were released immediately after the plants were treated. In the other series, the weevils were released 24 hours after the plants had been sprayed. All plants in both series were in the field exposed to normal environmental conditions. In this field experiment the toxicities of TM-711, TM-4049, parathion and gamma benzene hexachloride-DDT, 3-5 (γBHC-DDT) were compared to toxaphene. As indicated in the previous experiment the toxicity of the phosphorus compounds and TM-711 was greatly reduced in 24 hours. The toxicity of toxaphene and γBHC-DDT was also greatly reduced in 24 hours by sunshine, dew etc. The toxicity of toxaphene was reduced more in this experiment than in any others which was due in part to the increasing resistance of the weevils to poisons late in the season.

During a year when the daily temperatures were excessively high and the relative humidity low, it required high dosages of all the organic insecticides to effect high mortalities of boll weevils. It

Table 3.—Results of laboratory cage toxicity tests for boll weevil control using insecticides indicated applied as sprays in experiment 3 at College Station, Texas.

Treatment	Date	Dose[1]	Per Cent Mortality			Per Cent Reduction in Toxicity in 24 Hours	
			Immediate Release[2]	Laboratory[3]	Outside[4]	Laboratory[3]	Outside[4]
Toxaphene	7/27[5]	1.50	100.0	100.0	87.8		
	8/1	1.00	96.6	93.7	76.9		
Average		1.25	98.3	96.8	81.8	1.5	16.8
EPN	7/27	.30	95.3	100.0	100.0		
	8/1	.20	96.7	76.9	74.0		
Average		.25	96.0	88.4	87.0	7.9	9.4
Dieldrin	7/27	.30	100.0	100.0	87.3		
	8/1	.20	100.0	96.8	77.6		
Average		.25	100.0	98.4	82.4	1.6	17.6
TM-269	7/27	.10	100.0	100.0	65.6		
	8/1	.06	96.7	76.4	29.9		
Average		.08	98.3	88.2	47.7	10.3	51.5
Aldrin	7/27	.30	100.0	63.3	78.1		
	8/1	.20	67.5	63.8	41.6		
Average		.25	83.7	63.5	59.8	24.1	28.6

[1] Pounds active ingredients per acre.
[2] Weevils released onto plants immediately after treatment.
[3] Weevils released onto plants 24 hours after treatment. Treated plants stored in laboratory during the 24 hour period in which the maximum temperature was 94° F. on 7/26 and 7/31.
[4] Weevils released onto plants 24 hours after treatment. Treated plants were stored outside under natural conditions during the 24 hour period in which the maximum temperature was 100° F. on 7/26 and 104 ° F. on 7/31.
[5] The average maximum temperature during the 5-day test periods from 7/27 to 7/31 inclusive was 95.2° F. and from 8/1 to 8/5 inclusive was 95.8° F.

Table 4.—Results of field cage tests for boll weevil control using insecticides as indicated applied as sprays in experiment 4 at College Station, Texas.

Treatment	Date	Source of Weevils[1]	Dose[2]	Per Cent Mortality		Per Cent Reduction in Toxicity in 24 Hours[5]
				Immediate Release[3]	24 Hour Delay[4]	
Toxaphene	7/27[5]	Squares	6.0	97.6	53.2	
	8/1	Squares	4.0	93.1	75.6	
	8/14	Bolls	4.0	67.3	52.9	
Average			4.7	86.0	60.6	29.5
EPN	7/27	Squares	1.0	89.0	82.4	
	8/1	Squares	.7	54.7	61.1	
	8/14	Bolls	.7	66.7	69.6	
Average			.8	70.1	71.0	0.0
Dieldrin	7/27	Squares	1.0	91.9	81.9	
	8/1	Squares	.7	98.1	85.8	
	8/14	Bolls	.7	73.0	67.3	
Average			.8	87.7	78.3	10.7
TM-269	7/27	Squares	1.0	97.4	84.9	
	8/1	Squares	.7	92.1	78.3	
	8/14	Bolls	.7	97.0	48.7	
Average			.8	95.5	70.6	26.1
Aldrin	7/27	Squares	1.0	78.6	62.1	
	8/1	Squares	.7	62.2	45.5	
	8/14	Bolls	.7	36.6	16.2	
Average			.8	59.1	41.3	30.1

[1] Weevils reared from punctured squares or bolls collected from infested fields.
[2] Pounds active ingredient per acre.
[3] Weevils released onto plants immediately after treatment.
[4] Weevils released onto plants 24 hours after treatment maximum temperatures during this 24 hour period were: 7/26, 100°; 7/31, 104°; 8/13, 106° F.
[5] The average daily maximum temperatures during the test periods beginning on the following dates were: 7/27, 102°; 8/1, 103.6° and 8/14, 105.7° F.

required 4 or more times as much toxicant to kill comparable percentages of weevils under field conditions than it did under laboratory conditions. High temperatures, sunshine, wide ranges in relative humidities, dew, or a combination of these factors greatly reduced the toxicity of the insecticides. Toxaphene, dieldrin and EPN retained more of their toxicity under these conditions than the other materials tested. In the laboratory tests TM-269 proved more toxic to weevils than dieldrin but this low dosage did not remain toxic when exposed to outside conditions for a 24 hour period. Under field conditions there was little difference in the toxicity of dieldrin and TM-269. Dieldrin remained more toxic than TM-269 following a 24 hour exposure to environmental conditions. The toxicity of aldrin was greatly reduced in the 24 hour period of exposure to normal environmental conditions and a high dosage failed to give effective control when the weevils were released onto the plants immediately after treatment.

It will be noticed that still higher dosages of insecticides were required to effect control of weevils late in the season during September and October as compared to July and August. The temperatures were higher in July and August than they were late in the season, indicating that high temperatures were not responsible for the reduction in toxicity of these poisons. These results as well as previous work referred to above indicate that factors other than environmental greatly affect the toxicity of organic insecticides to boll weevils. Results of experiment 1 and 2 indicate that the type of food upon which the larvae feed is an important factor. The boll fed weevils emerging late in the season have proved to be the least susceptible to insecticides.

Under field conditions late in the season parathion, TM-4049, TM-711 and γGHC-DDT were ineffective at rather high dosages and all of these materials exhibited poor residual toxicity.

Experiment 7 shown in table 7, was conducted in the laboratory for the purpose of determining the comparative toxicity of the following compounds to third instar cotton leafworms: (1) TM-269, (2) parathion, (3) TM-711, (4) dieldrin, (5) TM-4049, (6) aldrin, (7) TM-

Table 5.—Results of laboratory cage toxicity tests for boll weevil control using insecticides indicated applied as sprays in experiment 5 at College Station, Texas.

TREATMENT	DATE	DOSE[1]	PER CENT MORTALITY — Immediate Release[2]	DOSE[1]	PER CENT MORTALITY — 24 Hour Delay[3]	PER CENT REDUCTION IN TOXICITY IN 24 HOURS
Toxaphene	8/16[4]	1.00	66.8	1.00	58.4	
	9/13	1.00	44.2	1.00	67.4	
	9/24	.80	56.3[5]			
	10/1	1.25	85.7			
	10/10	.50	75.6			
Average		.91	65.7	1.00	62.9	.0
TM-1	8/16	1.00	100.0	1.00	74.4	
	9/13	1.00	53.8	1.00	55.8	
	9/24	.80	80.6			
	10/1	1.25	60.6			
	10/10	.50	59.0			
Average		.91	70.8	1.00	65.1	15.3
TM-711	8/16	.20	74.0	.20	52.5	
	9/13	.20	97.3	.20	63.7	
	9/24	.15	80.0			
	10/1	.025	40.5			
	10/10	.05	85.0			
Average		.12	75.4	.20	58.1	32.1
Parathion	8/16	.20	100.0	.20	47.2	
	9/13	.15	97.4	.15	48.4	
	9/24	.10	100.0			
	10/1	.025	25.9			
	10/10	.05	95.0			
Average		.10	83.7	.17	47.8	51.6
TM-4049	8/16	.20	100.0	.20	20.0	
	9/13	.15	57.8	.15	21.9	
	9/24	.10	79.5			
	10/1	.025	9.7			
	10/10	.05	100.0			
Average		.10	69.4	.17	20.9	73.5

[1] Pounds active ingredients per acre.
[2] Weevils released onto plants immediately after treatment.
[3] Weevils released onto plants 24 hours after treatment. Treated plants were stored outside under normal environmental conditions during this 24 hour delay period, maximum temperatures were: 8/15, 107°; 9/12, 88°; 9/23, 88°; 9/30, 88°; 10/9, 84° F.
[4] The average daily maximum temperatures during the tests beginning on the following dates were: 8/16, 92.2°; 9/13, 79.8°; 9/24, 85.4°; 10/1, 88.4° and 10/10, 79.2° F.
[5] The percentages on the following days were not included in calculating the per cent reduction: 9/24, 10/1, and 10/10.

1, (8) toxaphene and (9) γBHC-DDT. Dosage-mortality curves for the above mentioned materials are compared in figure 1. Toxaphene and TM-1 were equally effective for leafworm control, Parathion, TM-269 and EPN were highly effective. The new insecticides TM-269 and TM-711 were more toxic to the leafworm than either dieldrin or aldrin.

Experiment 8 shown in table 8, was likewise conducted in the laboratory for the purpose of comparing the residual toxicity of the insecticides compared in experiment 7 to control cotton leafworms. The toxicity of all the materials used at low dosages for leafworm control was greatly reduced by high temperatures, sunshine, dew etc. In most cases, the toxicity of the various materials was affected by the environmental tests. It is interesting to note that the toxicity of TM-269 at a dosage of 0.01 pounds per acre was reduced less in the 24 hour delay period than dieldrin applied at 0.03 pounds per acre. This was not the case in the weevil tests where dieldrin exhibited a better residual toxicity than TM-269.

Experiment 9, table 9, was conducted for the purpose of comparing the residual toxicities of EPN, dieldrin and TM-269 to that of toxaphene in tests to control third instar garden webworms. The dosages of the insecticides required to effect control of the webworms were higher than those required for leafworm control. Aldrin failed to give effective control at a comparatively high dose. Dieldrin did not prove as toxic to the webworm as TM-269 and did not remain as toxic as TM-269 following a 24 hour

Table 6.—Results of field cage toxicity tests for boll weevil control using insecticides indicated applied as sprays in experiment 6 at College Station, Texas.

Treatment	Date	Dose[1]	Per Cent Mortality — Immediate Release[2]	Dose[1]	Per Cent Mortality — 24 Hour Delay[3]	Per Cent Reduction in Toxicity in 24 Hours
Toxaphene	8/21[4]	4.0	56.2	4.0	43.2	
	8/28	5.0	77.7	5.0	41.6	
	9/4	5.0	64.5	5.0	29.7	
	10/18	6.0	85.3[5]			
Average		5.0	70.9	4.7	38.2	42.2
Parathion	8/21	.33	6.3	.33	13.2	
	8/28	.75	6.8	.75	6.2	
	9/4	1.25	79.3	1.25	12.9	
	10/18	1.00	71.9			
Average		.83	41.1	.78	10.8	64.9
TM-4049	8/21	.33	0.0	.33	26.3	
	8/28	.75	10.6	.75	0.0	
	9/4	1.25	32.1	1.25	0.0	
	10/18	1.00	73.2			
Average		.83	29.0	.78	8.8	38.0
TM-711	8/21	.33	21.7	.33	32.6	
	8/28	.75	17.7	.75	1.0	
	9/4	1.25	75.6	1.25	17.6	
	10/18	1.00	50.7			
Average		.83	41.4	.78	17.1	55.4
G. BHC-DDT	8/21	1.07	29.0	1.07	6.8	
	8/28	2.00	11.7	2.00	9.7	
	9/4	4.00	22.3	4.00	5.3	
	10/18	1.87	40.6			
Average		2.24	25.9	2.36	7.3	65.2

[1] Pounds active ingredients per acre.
[2] Weevils released onto plants immediately after treatment.
[3] Weevils released onto plants 24 hours after treatment, maximum temperatures during this 24 hour period were: 8/20, 98°; 8/27, 102°; 9/3, 106°; 10/17, 86° F.
[4] The average daily maximum temperatures during the test periods were: 8/21, 101.2°; 8/28, 103.2°; 10/18, 86.4° F.
[5] The percentages on 10/18 were not included in calculating the per cent reduction.

delay period exposed to normal environment. As indicated in the leafworm tests, TM-269 exhibited better residual toxicity than dieldrin. The toxicity of toxaphene and EPN was not greatly reduced during the 24 hour period when the plants were stored outside under the conditions of high temperatures, sunshine etc.

Table 7.—Dosage-mortality relationship of the compounds indicated applied as sprays in experiment 7 for cotton leafworm control at College Station, Texas.

Treatment	Pounds of Active Ingredients per Acre Required to Give— 50 Per Cent Mortality	90 Per Cent Mortality	Slope of Line
TM-269	0.002	0.008	1.762
EPN	0.002	0.006	2.548
Parathion	0.002	0.003	7.108
TM-711	0.009	0.041	1.997
Dieldrin	0.018	0.047	3.036
TM-4049	0.022	0.026	16.249
Aldrin	0.064	0.209	2.498
TM-1	0.069	0.131	4.613
Toxaphene	0.076	0.123	5.959
G. BHC-DDT	0.076	0.307	2.113

Experiment 10, table 10, had for its purpose (1) to compare the effectiveness of TM-269, TM-711, parathion, TM-4049 and EPN to that of toxaphene to third instar salt-marsh caterpillars and (2) to determine the toxicity of some of these materials following one-half inch of simulated rain. As in previous tests conducted at this Station, the one-half inch of simulated rain was applied soon after the sprayed plants had thoroughly dried. Following this treatment the worms were introduced onto the plants and the number of dead and live worms were recorded at the end of a 5-day period. The toxicity of the several insecticides varied considerably when used against the salt-marsh caterpillar. Parathion and TM-269 were more toxic than either TM-711, TM-4049, EPN or toxaphene. One-half inch of simulated rain reduced

Table 8.—Results of laboratory cage toxicity tests for cotton leafworm control using insecticides indicated applied as sprays in experiment 8 at College Station, Texas.

Treatment	Date	Dose[1]	Per Cent Mortality		Per Cent Reduction in Toxicity in 24 Hours
			Immediate[2] Release	24 Hour[3] Delay	
Toxaphene	9/5[4]	.03	5.1	2.7	
	9/11	.06	7.8	0.0	
	9/21	.15	98.1	76.0	
Average		.08	37.0	26.3	28.9
TM-1	9/5	.03	18.5	20.5	
	9/11	.06	22.6	0.0	
	9/21	.15	100.0	85.6	
Average		.08	47.0	35.4	24.7
EPN	9/5	.03	100.0	79.6	
	9/11	.02	95.1	0.0	
	9/21	.01	97.9	41.0	
Average		.02	97.7	40.2	58.9
Dieldrin	9/5	.01	0.0	2.3	
	9/11	.05	89.3	11.1	
	9/21	.03	91.9	42.6	
Average		.03	60.4	18.7	69.0
TM-269	9/5	.02	98.2	62.3	
	9/11	.015	83.2	25.2	
	9/21	.01	97.9	91.9	
Average		.01	93.1	59.8	35.8
Aldrin	9/5	.02	3.5	2.5	
	9/11	.08	25.2	0.0	
	9/21	.15	90.6	80.4	
Average		.08	39.8	27.6	30.7
TM-711	9/5	.02	73.2	3.7	
	9/11	.015	45.0	0.0	
	9/21	.01	82.6	12.9	
Average		.01	66.9	5.5	91.8
Parathion	9/5	.03	98.2	80.5	
	9/11	.02	100.0	100.0	
	9/21	.01	100.0	42.3	
Average		.02	99.4	74.3	25.3
TM-4049	9/5	.03	92.4	0.0	
	9/11	.02	26.8	0.0	
	9/21	.025	97.7	x.0	
Average		.02	72.3	.7	99.0
G.BHC-DDT	9/5	.08	4.6	1.8	
	9/11	.16	60.7	7.8	
	9/21	.21	81.9	65.8	
Average		.15	49.1	25.1	48.9

[1] Pounds active ingredients per acre.
[2] Worms released onto plants immediately after treatment.
[3] Worms released onto plants 24 hours after treatment. The treated plants were stored outside under normal environmental conditions during this 24 hour delay period, maximum temperatures were: 9/4, 100°; 9/10, 90°; 9/20, 90° F.
[4] The average daily maximum temperatures during the test periods beginning on the following dates were: 9/5, 93.4°; 9/11, 82.8°; and 9/21, 85.4° F.

the toxicity of the materials in the following ascending order: toxaphene, TM-269, TM-711 and parathion.

SUMMARY.—Results of field cage tests indicated that overwintered weevils were more susceptible to toxaphene spray than weevils reared from squares during the early fruiting season. Apparently the depletion of food in the overwintered weevils affected their susceptibility to toxaphene. It was also found that about 4 times as much toxaphene was required to kill weevils reared from bolls than

Table 9.—Results of laboratory cage toxicity tests for garden webworm control using insecticides indicated applied as sprays in experiment 9 at College Station, Texas.

Treatment	Date	Dose[1]	Per Cent Mortality		Per Cent Reduction in Toxicity in 24 Hours
			Immediate[2] Release	24 Hour[3] Delay	
Toxaphene	8/16[4]	1.00	89.5	77.0	
	8/14	2.00	96.9	90.4	
Average		1.50	93.2	83.7	10.2
EPN	8/16	.05	100.0	62.6	
	8/14	.10	87.2	84.1	
	8/3	.20	70.5	100.0	
	8/6	.30	100.0	100.0	
Average		.16	89.4	86.7	3.0
Dieldrin	8/16	.125	50.0	0.0	
	8/14	.25	93.0	38.6	
	8/3	.33	94.9	45.3	
	8/6	.50	74.7	54.7	
Average		.30	78.1	34.6	55.7
TM-269	8/16	.125	96.4	33.3	
	8/14	.25	100.0	82.5	
	8/3	.33	94.4	96.2	
	8/6	.50	100.0	100.0	
Average		.30	97.7	78.0	20.2
Aldrin	8/16	.125	2.6	8.7	
	8/14	.25	42.6	21.1	
	8/3	.33	39.7	10.1	
	8/6	.75	77.3	2.5	
Average		.36	40.5	10.6	73.8

[1] Pounds active ingredients per acre.
[2] Worms released onto plants immediately after treatment.
[3] Worms released onto plants 24 hours after treatment. The treated plants were stored outside under normal environmental conditions during the 24 hour delay period, maximum temperatures were: 8/2, 100°; 8/5, 105°; 8/13, 106°; and 8/15, 107° F.
[4] The average daily maximum temperatures during the test periods beginning on the following dates were: 8/3, 98°; 8/6, 99.2°, 8/14, 99°; and 8/16, 98.2° F.

from squares. These data indicated that the type of food upon which the weevils develop affects their susceptibility to toxaphene.

The results of all the weevil tests indicate that it required 4 or more times as much toxicant of the various materials to effect comparable kill in the field than in the laboratory. Such factors as high temperatures, sunshine, wide ranges in relative humidity, dew, or a combination

Table 10.—Results of laboratory cage toxicity tests for salt-marsh caterpillar control using insecticides as indicated applied as sprays in experiment 10 at College Station, Texas. (Eight replicates in all tests.)

Treatment	Dose[1]	Total No. Worms[2]	No Rain	Simulated Rain[3]	Reduction in Toxicity
Toxaphene	.350	82	97.43	81.24	16.62%
TM-269	.025	80	94.73	73.65	22.25
TM-711	.100	80	94.73	61.82	34.74
Parathion	.015	77	82.22	22.40	72.76
TM-4049	.015	80	9.15		
EPN	.015	81	27.19		

[1] Pounds active ingredients per acre.
[2] Total number worms in the 8 replicate cages under each condition.
[3] One-half inch of simulated rain applied to plants after insecticidal treatment.

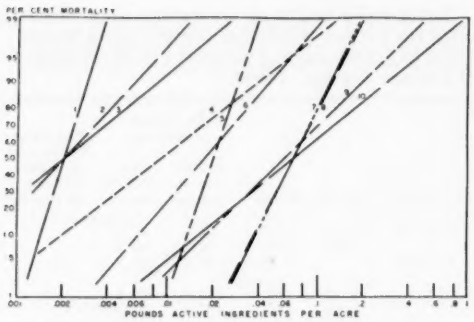

FIG. 1.—Dosage mortality curves for the toxicity of the following insecticides to cotton leafworms: (1) parathion, (2) EPN, (3) TM-269, (4) TM-711, (5) TM-4049, (6) dieldrin, (7) TM-1, (8) toxaphene, (9) aldrin and (10) G.BHC-DDT.

of these factors greatly reduced the toxicity of the insecticides tested. Toxaphene, TM-1, dieldrin and EPN retained their toxicity for weevils under these environmental conditions better than the other materials tested. The toxicity of parathion, TM-4049, TM-711, γBHC-DDT, TM-269 and aldrin was greatly reduced by the environmental factors listed above.

It was found that it required higher dosages of the insecticides to effect control of weevils late in the season as compared to the early season. Factors other than environmental effected the toxicity of organic insecticides to boll weevils. Here again, the food upon which the weevils develop may be partially responsible for this resistance to insecticides late in the season.

Most of the insecticides tested proved toxic to the cotton leafworm at rather low dosages. Dieldrin did not prove as toxic to the leafworm as TM-269 and TM-711 proved more toxic than aldrin. The toxicity of all the insecticides used at these low dosages was greatly reduced by high temperatures, sunshine, etc.

Toxaphene and TM-1, a chlorinated terpene, were equally effective against the boll weevil and leafworm.

Dieldrin or aldrin did not prove as toxic to garden webworms as TM-269. The residual toxicity of TM-269 was better than that of dieldrin in the leafworm and webworm tests. In these tests the toxicity of toxaphene and EPN was not greatly reduced by high temperatures, sunshine, etc.

One-half inch of simulated rain reduced the toxicity of the materials when used against salt-marsh caterpillars in the following ascending order: toxaphene, TM-269, TM-711 and parathion.

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ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The twenty-third Annual Meeting of the Rocky Mountain Conference of Entomologists will be held at Cameron Pass Camp, Fort Collins, Colorado, during the period beginning August and ending August 21, 1952.

Details of the plans and general information needed by those who plan to attend may be secured by addressing the Chairman, Dr. T. R. Robb, at Fort Collins.

The Camp offers a very profitable program of papers and discussions with a mountain vacation at a 9000 foot elevation. Those who have attended in the past have spoken highly of the advantages of the situation and the quality of the programs which have been presented in former years. Dr. Geo. M. List is Secretary of the Conference and has had experience with the previous meetings since the inception of the idea.

Tests for Control of Meadow Spittlebugs in Ohio[1]

D. D. Ahmed,[2] B. A. App, Ray T. Everly,[3] and R. H. Davidson[4]

During the seasons of 1948 and 1949, field tests of a number of organic insecticides as sprays were made for the control of the meadow spittlebug, *Philaenus leucophthalmus* (L.), an insect which the last few years has become increasingly abundant in forage and other crops and has caused serious reductions in forage yields.

Mundinger (1946) reported tests for spittlebug control on strawberries and alfalfa with several insecticides of which the most promising were a 1-per cent rotenone dust at 50 pounds per acre or 5 pounds of derris in 100 gallons of water at 300 gallons per acre. Scholl & Medler (1947) dusted trap strips with DDT and obtained good control of adult spittlebugs, leafhoppers, and plant bugs. Chamberlin *et al.* (1948) reported that on strawberries, sweetclover, and alfalfa in Wisconsin, chlordane controlled spittlebug nymphs more effectively than either DDT or benzene hexachloride, both of which gave some control. Pederson & Sherman (1948) reported that on strawberries in Michigan a spray containing 1.5 pounds of benzene hexachloride (6 per cent gamma) per 100 gallons of water applied at the rate of 450 gallons per acre gave nearly perfect control. Wilson (1949) stated that DDT, chlordane, methoxychlor, and parathion gave highly significant control of adult spittlebugs the first week after treatment. Chamberlin & Medler (1949) reported that on alfalfa toxaphene at 1.5 pounds per acre furnished good control of spittlebug nymphs and that benzene hexachoride at 0.133 pound of the gamma isomer per acre showed some promise.

Several articles on the control of the meadow spittlebug have appeared since the studies reported in the present paper were conducted. They include papers by Weaver (1950, 1951), Gyrisco & Marshall (1950), Chamberlin & Medler (1950), Marshall & Gyrisco (1951), Parks & Weaver (1951), and Menusan (1951).

Tests Conducted in 1948.—In 1948 the tests were conducted on a field of mixed hay containing timothy, alfalfa, red clover, and alsike clover on the Ohio State University farm at Columbus. The treated area was divided into 70 plots, each 10 by 15 feet. Thirteen treatments were applied in a randomized block design, and each treatment was replicated five times. Included also was a series of untreated plots. All the insecticides were applied with a hand-operated compressed-air sprayer.

One week after the insecticides had been applied nymphal populations were recorded from two 1-square-foot samples selected at random in each plot. The data for these tests are given in table 1.

Benzene hexachloride was the most effective material used in these tests and the difference between the wettable-powder and emulsion sprays was not significant. The three forms of DDT showed varying degrees of toxicity. The wettable-powder spray and the colloidal form were significantly less toxic than benzene hexachloride whereas the emulsion spray was not. The difference between the two forms of chlordane was not significant, and their toxicity did not differ significantly from that of benzene hexachloride. Toxaphene was not significantly different in toxicity from chlordane or from benzene hexachloride. Parathion at the dosage applied gave poor control. The pyrethrum and rotenone sprays were ineffective in controlling spittlebug nymphs. Analyses of the total numbers of stems per square foot showed that there were no significant differences among the treatments. The data obtained were not considered to be affected by differences in stand and therefore they were not corrected for stand variations.

Tests Conducted in 1949.—During the 1949 season benzene hexachloride, chlordane, methoxychlor, aldrin, heptachlor, and toxaphene were applied to 18- by 30-foot plots of red clover arranged in a randomized block in which each treatment was replicated four times. DDT, para-

[1] The research reported in this paper was conducted at the Legume Seed Research Laboratory, Columbus, Ohio, maintained by the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, Soils, and Agricultural Engineering of the U. S. Department of Agriculture in cooperation with the Ohio State University.

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[3] Bureau of Entomology and Plant Quarantine. Mr. Everly resigned on June 30, 1948; now associate in entomology, Purdue University Agricultural Experiment Station.

[4] Associate professor of Entomology, Ohio State University.

Table 1.—Effectiveness of various insecticide sprays for the control of meadow spittlebug nymphs. 1948.

Insecticide Formulation	Active Ingredient per Acre	Stems per Square Foot	Stems Infested	Nymphs per Square Foot	Reduction in Nymphs per Square Foot
	Pounds	*Number*	*Per Cent*	*Number*	*Per Cent*
None	—	31.3	49.3	132.4	—
DDT:					
Wettable, 50%	4	36.9	37.4	50.5	62
Colloidal, 40%	4	35.9	35.2	45.5	66
Emulsifiable, 25%	4	32.0	23.2	15.0	89
Benzene hexachloride:					
Wettable, 6% gamma	1	25.6	.7	.5	99+
Emulsifiable, 5.625 gamma	1	29.3	4.0	4.3	97
Chlordane:					
Wettable, 50%	2	31.1	31.2	34.4	74
Emulsifiable, 40%	2	33.7	20.5	18.6	86
Parathion, wettable 25%	1	28.5	34.7	64.3	51
Toxaphene, wettable 25%	2	34.4	24.8	24.1	82
Piperonyl butoxide 10% and pyrethrins 0.5%, wettable	1[1]	33.1	52.3	103.1	22
Piperonyl cyclonene 4% and pyrethrins 0.4%, emulsifiable	1	38.5	46.0	144.0	+9
Piperonyl cyclonene 4% and rotenone 1% wettable	½	35.7	41.8	101.7	23
Emulsifiable	1	33.6	48.3	95.2	28
Least significant difference:					
At 5% level		Not	13.1	34.1	
At 1% level		sig.	17.3	45.4	

[1] Indicated dosages are for the combined ingredients.

thion, and synergized rotenones and pyrethrins were omitted because of their poor showing in 1948. Chlordane and toxaphene were used as emulsions and the other materials as wettable-power sprays. Applications were made on two dates—one on May 6 before all of the spittlebug egg had hatched and the other on May 17 when hatching was believed to be complete. The early applications were made with a small manually operated sprayer having a 10-foot boom, and the late application with a hand-operated compressed air sprayer.

To evaluate the materials, five stems selected at random in each of five points in each plot, or 100 stems per treatment, were examined and the population of spittlebug nymphs recorded. A wire rod 36 inches long marked with 5 bands of red paint was dropped at random and the nearest stem to each band was examined. Population counts in the plots treated on May 6 were taken on May 13 and 23. The data are summarized in table 2.

In the counts taken on May 13 the greatest reduction in the number of nymphs was obtained with benzene hexachloride. Methoxychlor was second, and heptachlor, toxaphene, and chlordane were about equal in their effectiveness. Aldrin gave the lowest per cent control.

In the counts taken on May 23 some slight changes in nymphal populations were noticeable. For instance, the populations increased in plots treated with benzene hexachloride and aldrin, whereas they decreased in those treated with chlordane, methoxychlor, and toxaphene. These slight changes in effectiveness of the different insecticides over a period of 10 days may have been due to their mode of action or to the presence or absence of a residual deposit. It is also possible that some eggs hatched during this period. The compounds that were slow acting or had a residual deposit may have continued to kill the old as well as the newly hatched nymphs, while those that lacked such action failed to do so. Consequently, the former condition caused further reductions while the latter allowed increases in nymphal population.

In the treatments made on May 17 (Table 3) benzene hexachloride and methoxychlor were again the most effective insecticides, followed by heptachlor, chlordane, aldrin, and toxaphene. Toxaphene, for some unexplained reason, was much less effective than in the earlier

Table 2.—Effectiveness of various insecticides applied to red clover on May 6, 1949, for control of meadow spittlebug nymphs

TREATMENT	ACTIVE INGREDIENT PER ACRE	COUNTS ON MAY 13, 1949			COUNTS ON MAY 23, 1949		
		Stems Infested	Total Nymphs	Reduction in Nymphs	Stems Infested	Total Nymphs	Reduction in Nymphs
	Pounds	*Number*	*Number*	*Per Cent*	*Number*	*Number*	*Per Cent*
None	—	75	314	—	77	271	—
γ-Benzene hexachloride	1	8	19	94	24	49	82
Chlordane	2	25	78	75	10	14	95
Methoxylchlor	8	19	41	87	11	15	94
Aldrin	1	38	114	64	37	121	55
Heptachlor	2	33	79	75	25	49	82
Toxaphene	2	31	83	74	20	32	88
Least significant difference:							
At 5% level		19.4	87.4	—	19.2	90.1	—
At 1% level		26.6	119.7	—	25.2	123.1	—

applications.

CAGE TESTS AGAINST THE ADULTS.—Cage tests were carried out in an outdoor insectary on adult spittlebugs that were confined within wire-screen cages over potted clover plants. The cages were cylindrical, 6 inches in diameter and 14 inches tall, and fitted snugly into 8-inch pots. The insects were introduced through the open tops of the cages. The cage with the insects was inserted three-fourths its length up into a spray tower and sprayed. It was then covered with a piece of cheesecloth secured by a rubber band. The spray tower used is similar to that described by Waters (1943), with slight modifications in the method of supplying the air (which came from a compressed-air tank) and of delivering the insecticide. The required amount of the insecticide was suspended in water so that a 10-ml. aliquot gave the desired dosage.

The results of these tests are shown in table 4. DDT and methoxychlor gave equally good control at 6 pounds and 2 pounds to the acre. Benzene hexachloride at 4 pounds and at 2 pounds of the gamma isomer per acre reduced populations somewhat less than did either DDT or methoxychlor at 2 pounds to the acre. Chlordane and toxaphene at the dosages used were less effective than either DDT or methoxychlor.

The results herein reported are purely experimental in nature and do not constitute recommendations for the use of any of the insecticides tested.

SUMMARY.—In 1948 and 1949 at Columbus, Ohio, field experiments with various insecticides were conducted for the con-

Table 3.—Effectiveness of various insecticides applied on May 17, 1949, for control of meadow spittle-bug nymphs. Counts made on May 23.

TREATMENT	ACTIVE INGREDIENT PER ACRE	STEMS INFESTED	TOTAL NYMPHS	REDUCTION IN POPULATION
	Pounds	*Number*	*Number*	*Per Cent*
None	—	65	257	—
γ-Benzene hexachloride	1	1	1	99+
Chlordane	2	23	52	80
Methoxychlor	8	6	12	95
Aldrin	1	41	92	64
Heptachlor	2	20	39	85
Toxaphene	2	46	146	43
Least significant difference:				
at 5% level		25.6	90.7	
At 1% level		35.1	124.2	

Table 4.—Cage tests of various insecticides in wettable-powder sprays against adults of the meadow spittlebug. August 1949.

INSECTICIDE	ACTIVE INGREDIENT PER ACRE	ADULTS	REDUCTION
	Pounds	*Number*	*Per Cent*
DDT	6	50	98
	2	50	95
	1	50	70
Chlordane	4	25	80
	2	50	38
Methoxychlor	6	25	100
	2	50	98
	1	50	41
γ-Benzene hexachloride	4	25	88
	2	50	71
	1	50	41
Toxaphene	2	25	50

trol of nymphs of the meadow spittlebug, *Philaenus leucophthalmus* (L.), on red clover. Limited studies on the effect of different insecticides on the adults were made in cages.

Results obtained in 1948 indicated that benzene hexachloride at 1 pound of the gamma isomer per acre furnished excellent control. Chlordane and toxaphene each at 2 pounds and DDT at 4 pounds per acre were somewhat less effective. Parathion at 1 pound per acre, and synergized rotenone and pyrethrins gave very poor results.

Benzene hexachloride, chlordane, methoxychlor, aldrin, heptachlor, and toxaphene were tested in 1949. Applications made on May 6 and May 17 gave about equal results. Benzene hexachloride at 1 pound of the gamma isomer per acre and methoxychlor at 8 pounds were the most effective. Chlordane, heptachlor, and aldrin were less effective. Toxaphene at 2 pounds was much less satisfactory when applied on May 17 than on May 6.

In cage tests against the adults, DDT and methoxychlor at 2 pounds per acre gave a much higher degree of control than chlordane, benzene hexachloride, and toxaphene at comparable dosages.

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PESTICIDE HANDBOOK compiled and edited by Dr. Donald E. H. Frear, 176 pp., 1952, Fourth Edition. College Science Publishers, State College, Pennsylvania, Price $1.25.

This attractive paper covered volume lists alphabetically over 4,400 trade names of pesticides. It not only includes many more pesticidal materials than previous editions, but has added a listing of animal repellents and a section on compatibilities and hazards of the common pesticides.

Following the alphabetical list of pesticides in Section I are classified lists including adjuvants, diluents, fungicides, fungicide-insecticide combinations, herbicides, insecticides, plant hormones, seed treatments, wood preservatives, rodenticides and equipment. The insecticides are subdivided into aerosols, dips, sprays, baits, etc. The large and ever increasing number of pesticidal materials on the market make this an extremely useful reference work.

F. C. BISHOPP

Effects of Aldrin and Dieldrin on Germination and Early Growth of Field Crop Seeds[1]

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The advent of the potent new chlorinated hydrocarbon insecticides and the recognition of their potential value as soil insecticides have posed a number of problems. Among these are the effects of these chemicals on the various crops grown on the soils in which their application may be required for satisfactory insect control. Obviously an insect control practice, regardless of its efficiency from the entomological standpoint, cannot be recommended if it is seriously detrimental to the crops it is designed to protect.

The investigation to be reported here dealt with the effects of various levels of aldrin and dieldrin on the germination and early growth of a variety of field crops which are grown commercially in the Middle West. These experiments were carried out in the greenhouse under conditions considered far more severe than would ordinarily be encountered by normal use in the field. This work has formed the basis for field applications that would have been considered hazardous if these results had not been available.

Materials and Methods.[2]—The insecticides tested were aldrin equivalent, recrystallized aldrin, and dieldrin. All were used as wettable powder formulations containing 25 per cent of active ingredients. The 25 per cent aldrin equivalent preparation contained 23.8 per cent aldrin and 17.9 per cent related compounds, and was considered by the manufacturer to be the equivalent of 25 per cent aldrin. The recrystallized aldrin formulation contained 25 per cent aldrin and no related active compounds. The dieldrin formulation contained 21.2 per cent dieldrin and 3.8 per cent related active compounds, and was rated by the manufacturer as the equivalent of 25 per cent dieldrin. In this report aldrin equivalent will be designated as aldrin unless otherwise specified.

Washed river sand was used throughout as the planting medium. It had the important practical advantage that it could be readily washed from the roots when the green weights were obtained. Also it lacked organic matter, which presumably tends to tie up insecticides in soil and thus slow down their insecticidal action (Cullinan 1949; Fleming & Maines 1947). Related studies with seed treatments indicate that phytotoxic substances tend to produce more severe symptoms in sand than they do in soil. A mixed commercial fertilizer[3] was used throughout on the premise that one of the easiest ways to add an insecticide to the soil is its use in the form of an insecticide-fertilizer mixture.

All of the mixing was done in a closable rotating drum mounted on a horizontal shaft at approximately a 45° angle. The sand was measured by filling to a depth of 3 inches the 20 by 14 by 3.5 inch greenhouse flat box in which it would eventually be used. After slight moistening it was dumped into the mixer and the proper amounts of fertilizer and insecticide (both calculated on the basis of surface area) were added. After closing, the drum was slowly rotated 100 revolutions to insure thorough mixing. Fresh insecticide-fertilizer-sand mixtures were made up for each test.

An improvised furrow-maker was used which gave straight rows and a uniform planting depth for a given crop. Flat boxes of the size indicated were ample for 6 or 8 rows of the small-seeded crops and 4 or 5 rows of corn. Each row received 20 or 25 kernels of corn, 33 or 34 soybeans, or 50 seeds of the smaller-seeded crops. In all cases each replicate consisted of 100 seeds. Thus in the small-seeded crops a single flat was adequate for one replicate of each of three or four different crops (6 or 8 rows planted with 50 seeds each). Usually two replicates of each treatment were run in a given experiment, and further replications were obtained by making subsequent runs.

The flat box positions on the greenhouse benches were determined by the use of tables of random numbers. The object was to equalize the effects of whatever differences were present at different positions,

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[1] This investigation was supported in part by a research grant from the Shell Chemical Corporation, New York, New York, and the Julius Hyman Company, Denver, Colorado.

[2] The insecticides used in this investigation were furnished by Julius Hyman and Company, Denver, Colorado.

[3] Rath's 3-12-12.

Table 1.—Results of corn experiment with two insecticides employed at eight levels. (Means expressed in terms of mean green weight per plant).

	Dosage in Pounds per Acre								
Insecticide	0	2	4	8	16	32	64	128	Avg.
Aldrin	2.22	2.28	2.07	2.06	1.87	1.74	1.73	1.64	1.95
Dieldrin	2.23	2.25	2.34	2.27	2.14	2.01	2.12	2.02	2.17
Avg.	2.23	2.26	2.21	2.16	2.00	1.88	1.93	1.83	

The standard error of an individual treatment mean = .0547.

particularly in regard to temperature. All flats were watered routinely and as evenly as possible.

The procedures for taking data were similar to those employed by Foster (1951). The emergence counts were usually made from 3 to 5 days after the first emergence was observed. At this time the plants were removed from the sand, special care being taken to keep the root systems intact. It was assumed that any injurious effects of the insecticides would show up as reduced emergence, or as stunted or deformed growth of the young seedlings. The object was to take the data and end the experiments before photosynthesis had occurred to the extent that it would permit the seedlings to outgrow any early adverse effects. In the case of corn, it has been reported that its growth can be divided into several distinct periods Briggs *et al.* 1921. During the first period, usually lasting about 3 weeks under ordinary growing conditions, the plants plus the kernels weigh less than the original kernels. After this there is a rapid increase in plant weight.

After removing the plants from the boxes the roots were washed thoroughly to remove all of the sand, and each group was shaken 5 times to remove the excess water. The group was then weighed promptly and the green weight recorded. The average green weights were eventually calculated from the emergence records and the green weight readings.

Seeds from known sources and varieties were used so far as possible, and the official germination of each seed lot was determined by the Iowa State College Seed Testing Laboratory. The crops, varieties, and germination percentages were as follows: Moore barley, 96 per cent; buckwheat, 94 per cent; U. S. 13 corn, grade MF, 99 per cent; Redwing flax, 92 per cent; Clinton oats, 96 per cent; Balbo rye, 86 per cent; Honey sorghum, 96 per cent; Lincoln soybean, 73 per cent; and Iohardi winter wheat, 89 per cent.

Results.—Early in this investigation there were important questions in regard to the size and number of replicates required, variability from row to row within flats, and green weight differences due to temperature variation from one part of the greenhouse bench to another. To obtain information bearing on these points an experiment was carried out with corn, using 8 levels of each of the two insecticides, and replicate flat boxes, each consisting of 4 rows planted with 25 seeds, harvested and weighed separately by rows. A detailed statistical treatment of these data led to the conclusions given below.[1]

The mean green weights per plant for the 16 treatment combinations (2 insecticides, each at 8 levels) differed significantly at the 1 percent probability level. Also the 3 components (insecticides, levels and interaction between the two factors) of the treatment effects were studied separately. The variation in weights among levels of insecticide was significant, as was the mean difference between the two insecticides. In addition, there was a significant interaction between insecticides and levels. The average rate of the decrease in green weights per plant as the level of insecticide increased was greater with aldrin than with dieldrin. Table 1 lists the various insecticide and level means with the standard error of these means.

The analysis of variance based on the means by rows, planted with 25 seeds, showed that the variation among rows within flats was small as compared to variation among flats. Had only 3 rows been used instead of 4, the loss in efficiency in estimating treatment effects

[1] The authors are indebted to Mr. Robert Bowles, formerly of the Iowa State College Statistical Laboratory, and Professor P. G. Homeyer of the same Laboratory, for the analyses of these results and the conclusions based on them.

would have been only about 12 per cent. In the remaining experiments weights and other data were obtained by flats rather than individual rows.

The effect of temperature on seedling growth was also studied. Although a definite relationship was found between plant weight and soil temperature, as evidence by a correlation of .51 (significant at 1 per cent level), after replicate effects were acounted for, only 13 per cent of the error variation could be explained by soil temperature differences. This resulted because the between replicates plant weights were more highly correlated with soil temperature than within replicates. Hence it was deemed unnecessary to correct plant weights for soil temperature since this variation, for the most part, is corrected for when the replicate variation is taken out.

A summary of the large volume of detailed data accumulated in this investigation is presented in tables 2 and 3 and in figure 1. The main findings are discussed separately for the various crops, which are listed alphabetically in the discussion below.

DISCUSSION.—*Barley.* This crop was very tolerant of aldrin in concentrations up to 64 pounds per acre, at which levels some effect on emergence was evident (Table 2). However, it was only at 128 pounds per acre that emergence was severely affected. Dieldrin had no effect, except perhaps slight stimulation, even at the highest dosage.

It is in the green weight data that differences in response to dosage levels are most apparent. Table 3 shows that 2 pounds of aldrin per acre caused a drop in the average plant weight of only .003 gram, whereas four pounds per acre caused a drop of .03 gram—a ten-fold decrease. These figures appear small, but it must be remembered that the average green weight per untreated plant was only .289 gram. Dieldrin also caused a suppression of growth but it was very slight for each increase in application level.

Aldrin at both the 64- and 128-pound levels caused some deformity of plant growth. Instead of assuming a vertical position, many of the plants grew out at various angles from the surface of the sand.

Buckwheat. Aldrin at application levels above 8 pounds per acre caused decreased emergence, as shown in table 2. The 32-pound level appears to have caused the second largest decrease in per cent emergence. This level in one replicate was extremely low and this one value lowered the average of the three replicates. Dieldrin had practically no effect on emergence, even at the highest dosages. Emergence at the 128-pound level was only 4.7 per cent below the untreated control.

The average green weights decreased rather sharply when aldrin was used at levels of 4 to 16 pounds per acre (Table 3). The plants at the latter level averaged a little more than half the green weight of those at the control (zero) level. Beyond the 16-pound dosage of aldrin there was a gradual increase in average green weights up to and including the highest level. The effects of dieldrin on green weights were not as great as those recorded for aldrin. However, there was a slight but constant decrease in the mean green weights up to the highest level of application, following a slight initial increase at the two-pound level. Evidence of plant stimulation by low levels of soil insecticides is available in current entomological literature Stone & Smith 1951.

Corn. Of all the crops tested corn showed the greatest tolerance to high levels of insecticides in the sand medium used in these experiments. Table 2 shows that the greatest decrease in emergence was only 2 per cent at the 64-pound per acre dosage of aldrin. At 128 pounds per acre it caused an average suppression of emergence of only 0.3 per cent under the untreated control. In the dieldrin series, emergence was consistently higher than the untreated control at all levels.

The mean green weights for the corn plants grown at the various levels are presented in table 3. The fact that statistically significant differences were found both between the two insecticides and among the different treatment levels has been covered in detail in a previous section. The evidence of plant stimulation is quite striking for both the 4- and 8-pound levels of dieldrin.

All of the corn plants appeared normal, except that about 20 per cent of those grown at the 128-pound level of aldrin were visibly retarded. In general, it can be said that corn germinated and grew well at all levels of both insecticides.

Flax. Although the average germination of flax in these tests was approximately 12 per cent below the official germination

Table 2.—Emergence percentages for eight different crops grown in sand treated with aldrin and dieldrin, respectively. Treatment levels are given in pounds of technical insecticide per acre on an area basis.

Crop	Insecticide Level and Per Cent of Plants Emerged							
	0	2	4	8	16	32	64	128
				Aldrin				
Barley*	92.3	93.7	93.0	92.7	90.0	89.7	78.7	55.7
Buckwheat*	92.0	90.3	92.3	87.7	79.3	61.0	71.0	50.7
Corn*	99.0	99.3	99.3	98.7	98.3	99.0	97.0	98.7
Flax*	80.3	80.7	82.7	81.7	81.0	80.7	80.3	76.7
Oats†	97.4	94.6	77.6	54.0	41.8	35.6	20.8	30.6
Rye*	79.3	76.7	78.0	66.0	50.0	33.0	33.3	30.3
Soybeans‡	92.5	90.0	92.0	87.5	92.0	90.0	88.5	88.5
Winter Wheat†	79.4	83.0	81.4	76.0	69.0	64.0	64.8	66.8
				Dieldrin				
Barley*	92.3	92.7	94.7	94.7	92.7	91.3	92.7	94.7
Buckwheat*	92.0	89.0	90.0	90.3	91.7	90.7	90.0	87.3
Corn*	99.0	99.3	99.3	99.7	99.7	100.0	99.3	99.7
Flax*	80.3	81.3	83.7	82.0	78.3	81.7	82.3	82.3
Oats†	97.4	94.8	94.4	94.8	93.4	95.2	90.4	90.8
Rye*	79.3	73.0	77.3	77.7	78.3	78.3	78.0	71.7
Soybeans‡	92.5	93.5	93.0	93.5	94.0	91.0	94.0	93.0
Winter Wheat†	79.4	83.4	82.4	82.8	84.4	81.0	80.6	81.6

* Each value represents 300 seeds.
† Each value represents 500 seeds.
‡ Each value represents 200 seeds.

test, flax was very similar to corn in its tolerance to both aldrin and dieldrin. The first five levels of aldrin appeared to improve germination, as shown in Table 2. The 128-pound level caused only a 3.6 per cent reduction in emergence as compared with the untreated control. Dieldrin appeared to show a slightly greater stimulation of emergence for the first three levels of application than did aldrin at the same levels. However, the 16-pound level dropped two per cent below the average emergence in the untreated control. The emergence percentages for the three higher levels was slightly higher than for the control.

The data in table 3 showed that the green weights were somewhat variable for both insecticides. However, the first four levels of both compounds evidently stimulated plant growth, on the basis of the green weights obtained. Both compounds had about the same effect on growth at the 64- and 128-pound levels, but it was very slight in both cases.

Oats. Oats are relatively sensitive to aldrin in the growth medium, as shown in Table 2. Although 2 pounds of aldrin per acre caused a suppression in emergence of only 2.8 per cent, the 4 pound level suppressed emergence 19.8 per cent. This represents a seven-fold decrease when the dosage level was doubled. Emergence continued to decrease with each additional application level up through 64 pounds per acre, but the 128-pound level showed a slight increase above the 64-pound dosage. Not only was emergence suppressed at the higher dosages of aldrin, but the plants that did emerge were dwarfed. Dieldrin caused some suppression of emergence, with the maximum (7 per cent) occurring at the 64-pound level. The plants in the two highest dieldrin treatments were on the average about half as tall as those in the untreated control.

Both aldrin and dieldrin at the 2-pound level caused slight decreases in green weights, as shown in table 3. However, the differences were not great except at the 128-pound level of aldrin where the mean green weight was about 40 per cent below that for the untreated control. The greatest decrease recorded for dieldrin was approximately 15 per cent at the 64-pound level. Thus it is apparent that the deleterious effects on oats were much more evident in the emergence data than they were in the green weight records.

Rye. As indicated in table 2, the aldrin treatments above 4 pounds per acre caused the greatest drops in emergence percentages. The 2- and 4-pound levels

showed very little effect. The 64- and 128-pound levels of aldrin did not lower the per cent emergence much below that recorded for the 32-pound level. Dieldrin at the 2-pound level gave a 6.3 per cent reduction in emergence, which was second only to the 128-pound dosage with a 7.6 per cent reduction. The five levels between these two rates held the emergence down about 1.4 per cent below that for the untreated control.

Table 3 shows that the 2-pound level of each compound caused a decrease in average green weight of approximately 7.3 per cent below the control. The 4-, 8-, 16-, and 32-pound levels of both compounds gave results somewhat below the value obtained for the untreated control. The two compounds gave the same degree of suppression in green weights at the 64- and 128-pound levels. This amounted to 12.3 per cent under the control at the 64-pound level, and 19 per cent for the 128-pound dosage.

The rye plants in the aldrin series were visibly dwarfed at the 8-pound level and above.

Soybeans. Emergence in the untreated controls averaged almost 20 per cent higher than the official germination test for this lot of soybeans. Even in the poorest treatment the germination was 14.5 per cent higher than the official figures. Aldrin, although initiating no stimulation, did not produce serious suppression, as shown in table 2. The lowest emergence was only five per cent below the 92.5 per cent obtained for the control. The 64- and 128-pound levels of aldrin decreased emergence by only 4 per cent. Dieldrin appeared to stimulate emergence slightly at all levels, except at 32 pounds per acre where it dropped 1.5 per cent below the control.

Both compounds appeared to stimulate plant growth at the 2-pound level, where the mean green weights were 18.4 per cent above the value obtained for the untreated control. As shown in table 3, there was almost an equal decrease in the mean green weights between the 2- and 4-pound levels for both compounds, but even at 4 pounds they were both more than 11 per cent above the untreated control. Beyond this rate aldrin caused a decrease in green weights that reached a maximum of 18.8 per cent below the control at the 128-pound level. However, even these plants, though smaller, appeared quite normal. Dieldrin caused a slight drop in average plant weights at dosages above the 4-pound level, as compared with this treatment. However, none of the green weights for the dieldrin treatments fell below that for the untreated control.

Winter wheat. Although the 2-pound level of both aldrin and dieldrin shown in table 2 seemed to cause an increase in emergence over the untreated control, the results were still about 6 per cent below the official germination test of 89 per cent. After this initial increase the emergence began to decrease in the aldrin treatments, and continued to decrease up to the 32-pound level. At this rate and above the percent emergence held fairly constant. In the dieldrin treatments emergence fluctuated slightly for levels up to 32 pounds per acre and then remained quite constant. In none of the dieldrin treatments did the per cent emergence fall below the 79.4 per cent recorded for the control.

Although there was considerable fluctuation in the average green weights per plant for the first five dosages of both compounds shown in Table 3, these levels apparently did not cause any important stimulation or suppression. The plants in the flats containing the 64- and 128-pound levels of aldrin registered the greatest decreases in green weights. The average weight per plant at the 64-pound level of aldrin showed a decrease of 9 per cent below the control. When the rate of application was doubled (128 pounds per acre) the decrease in the average green weight was almost doubled (16.4 per cent). The greatest drop in plant weight due to dieldrin (8.5 per cent) came at the 64-pound level. At the 128-pound level the green weight was almost equal to that for the control.

The winter wheat plants grown at the 64- and 128-pound levels of aldrin were markedly dwarfed and "angled," and some chlorosis was evident.

Honey Sorghum. After a preliminary experiment showed honey sorghum to be very sensitive to aldrin, a test was carried out to see whether aldrin or the related compounds in the aldrin equivalent formulation were responsible for the greater degree of phytotoxicity caused by aldrin as compared with dieldrin. This was done

Table 3.—Average green weights of seedlings of eight different crops grown in sand treated with aldrin and dieldrin, respectively. Treatment levels are given in pounds of technical insecticide per acre on an area basis.

Crop	Insecticide Level and Average Green Weight in Grams							
	0	2	4	8	16	32	64	128
				Aldrin				
Barley*	0.289	0.286	0.250	0.226	0.207	0.183	0.158	0.165
Buckwheat*	0.266	0.261	0.233	0.158	0.148	0.149	0.153	0.157
Corn*	2.341	2.344	2.192	2.116	1.865	1.817	1.742	1.867
Flax*	0.088	0.097	0.097	0.091	0.090	0.082	0.087	0.075
Oats†	0.201	0.191	0.196	0.197	0.190	0.173	0.172	0.121
Rye*	0.163	0.151	0.147	0.155	0.149	0.149	0.143	0.132
Soybeans‡	1.216	1.443	1.351	1.229	1.209	1.054	1.102	0.944
Winter Wheat†	0.189	0.194	0.183	0.180	0.180	0.189	0.172	0.158
				Dieldrin				
Barley*	0.289	0.283	0.291	0.271	0.267	0.241	0.211	0.212
Buckwheat*	0.266	0.271	0.260	0.252	0.251	0.226	0.221	0.188
Corn*	2.341	2.335	2.432	2.400	2.185	2.102	2.110	2.086
Flax*	0.088	0.094	0.090	0.094	0.098	0.086	0.08	0.075
Oats†	0.201	0.195	0.200	0.187	0.187	0.185	0.170	0.177
Rye*	0.163	0.152	0.151	0.149	0.155	0.154	0.143	0.132
Soybeans‡	1.216	1.444	1.364	1.329	1.325	1.279	1.218	1.238
Winter Wheat†	0.189	0.180	0.189	0.184	0.187	0.187	0.173	0.186

* Each value represents 300 seeds.
† Each value represents 500 seeds.
‡ Each value represents 200 seeds.

by comparing the regular 25 per cent aldrin equivalent formulation with a 25 percent recrystallized aldrin wettable powder. The results shown in Figure 1 are quite striking.

Recrystallized aldrin had very little effect on germination. The greatest decrease in emergence was 6.5 per cent at the highest level, which in this experiment was 32 pounds per acre. Aldrin equivalent had relatively little effect on emergence at the 2- and 4-pound levels, but at 8 pounds per acre there was a 77.5 per cent drop in emergence. There was no emergence at either 16 or 32 pounds per acre of aldrin equivalent. It was interesting to note that almost all the seeds germinated in the flat boxes containing these high levels of aldrin equivalent, even though they failed to emerge. The plants that did emerge at the 8-pound level were dwarfed and retarded.

Kansas orange cane and Leoti red cane were also tested at the same time and in the same way as the honey sorghum. Both of these crops gave essentially the same results as the honey sorghum, except that the over-all emergence percentages were lower.

Aldrin equivalent caused a very steep drop in the averge green weight with each increasing level of application. At 8 pounds per acre the weight had dropped a total of 76.5 per cent, as compared with a drop of 26 per cent for recrystallized aldrin. The drop in green weight due to recrystallized aldrin was sharpest between the zero and 4-pound levels. Beyond four pounds per acre the drop was moderate and gradual. The maximum was 37.6 per cent at 32 pounds per acre.

Summary and Conclusions.—1. The effects of some of the more promising soil insecticides on plant growth need further study, and this investigation was undertaken to help fulfill this need.

2. The experiments were carried out in ordinary flat boxes in the greenhouse, using washed river sand as the growing medium. The principal data consist of germination records and green weight determinations, from which average green weights of the various seedlings were calculated. Some additional observations were made on abnormal growth and coloration.

3. The insecticides tested were aldrin equivalent, recrystallized aldrin, and dieldrin, all in 25 per cent wettable powder formulations. In most cases aldrin equivalent and dieldrin were used at eight different levels. (0, 2, 4, 8, 16, 32, 64 and 128 pounds of technical insecticide per acre on an area basis), in combination with

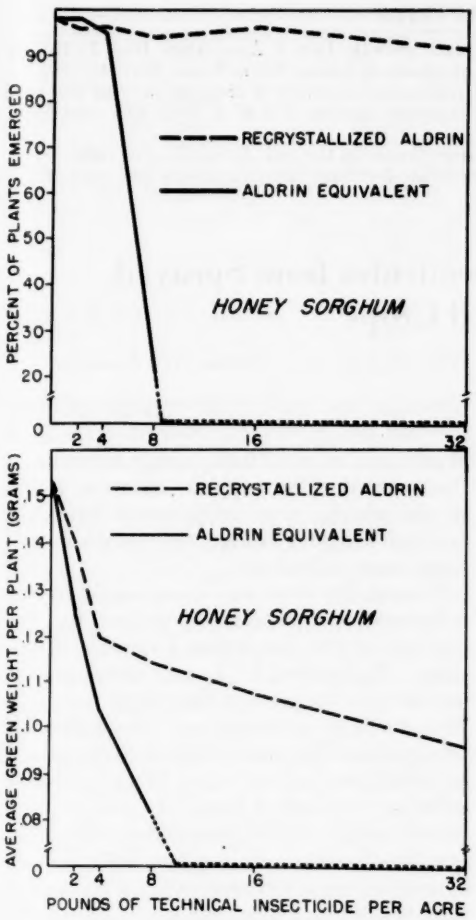

FIG. 1.—Per cent emergence and average green weights of seedlings of honey sorghum grown in sand treated with aldrin equivalent and recrystallized aldrin, respectively, at levels of 0, 2, 4, 8, 16 and 32 pounds per acre on an area basis.

3-12-12 commercial fertilizer at 200 or 300 pounds per acre.

4. The crops included in this study were buckwehat, corn, flax, oats, rye, honey sorghum, soybeans and winter wheat.

5. General results with aldrin equivalent were as follows: corn, flax and soybeans showed good emergence and growth at all levels, including the 128 pounds-per-acre rate. Barley emerged and grew well at levels up to and including 32 pounds per acre, and gave fair responses at the two higher levels. Buckwheat and winter wheat gave good emergence and growth at levels up to and including 8 pounds per acre, and fair responses above this level. Oats and rye gave good germination and growth at the 2- and 4-pound levels, fair responses at 8 and 16 pounds, and poor development at higher levels.

6. General results with dieldrin; all of the crops (barley, buckwheat, corn, flax, oats, rye, soybean and winter wheat) gave good emergence and seedling growth at all levels, up to and including 128 pounds per acre.

7. There were indications that some of the insecticide treatments slightly improved the per cent germination under the conditions of these experiments. Winter wheat and corn provided the most striking examples; with these crops the emergence percentages for the 2- and 4-pound levels of aldrin and all 7 levels of dieldrin were higher than that recorded for the control.

8. There was evidence of slight growth stimulation by both aldrin and dieldrin when they were used at relatively low levels (2 and 4 pounds per acre) on several of the crops tested.

9. Certain growth defects were noted on some of the crops, in addition to the stunting which is in part reflected in the green weight data. On both barley and winter wheat the 64- and 128-pound-per-acre levels of aldrin caused the young plants to grow out at various angles from the surface of the medium. Also the wheat seedlings exposed to these treatment showed definite chlorosis.

10. Honey sorghum was used as an indicator plant to determine whether aldrin or the active materials associated with it in commercial preparations of aldrin equivalent are phytotoxic. It was found that the associated materials were most phytotoxic, i.e., much better germination and growth were obtained with recrystallized aldrin than were obtained with aldrin equivalent at the same levels.

11. Since even the lowest dosage used in these experiments (2 pounds per acre) is higher than these materials would usually be applied as soil insecticides, they appear to have a high margin of safety so far as phytotoxic effects on common mid-western field crops are concerned.

12. Crops of the sorghum group may be an exception to point 11, but this possibility needs to be tested under field conditions before drawing a final conclusion. In any case, they provide useful "indicator" crops for phytotoxicity studies.

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Recovery of Organic Insecticides from Sprayed and Dusted Crops[1]

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During the 1951 growing season chemical analyses were made of insecticide residues remaining on clover and alfalfa crops sprayed or dusted with the following toxicants tested againts pea aphids, *Illinoia pisi*, and the spittle bug, *Philaenus spumarius*, L.: crude benzene hexachloride lindane, aldrin, dieldrin and toxaphene. Another series of field experiments was conducted with a new organic phosphorus insecticide applied as dust on corn to control the corn borer, *Pyrausta nubilalis*, Hbn.; on onions to control thrips, *Thrips tabaci*, Lind. and on lettuce and lima bean plants to study the rate of its disappearance. Chemically it is S-(1,2-dicarbethoxyethyl) 0, 0-dimethyl dithiophosphate and is designated throughout this paper as "4049". This toxicant is of special interest because, although related to parathion, it was found to be less poisonous to mammals.

EXPERIMENTAL.—The crops were grown on commercial farms and on the college experimental plots. The insecticides were applied by Filmer and Reed and the chemical analyses were made by Ginsburg with the assistance of Mr. J. E. Koles. Plant samples were collected soon after treatment; at several intervals prior to harvest and at harvest. The fresh samples were cut up in small pieces, transferred to glass jars and extracted with the solvent (2 cc. being used per gram of plant material) by shaking for about 1 hour. The solvent was then rapidly filtered and either analyzed immediately or stored in the dark for later analysis. In most instances 500 gm. of fresh plant material were used for each analysis. Samples from check plants were similarly treated and analyzed.

The chlorinated insecticides were determined by the total organic chlorine method, similar to that described by H. J. Wichman, *et al.* (1946), using benzene as the solvent. The organic chlorine found in the checks was substracted from the treated samples before the toxicant-residues were calculated.

Insecticide 4049 was determined by the colorimetric method, developed by Dr. Averell of the American Cynamid Company. Redistilled CCl_4 was employed as solvent for extracting the plant material. The method is based on the following principles: "The insecticide is decomposed by alkali in carbon tetrachloride-ethanol solution to diethyl fumarate and sodium 0,0-dimethyl dithiophosphate. The sodium 0,0-dimethyl dithiophosphate is then converted to the cupric salt which possesses an intense yellow color and is soluble in carbon tetrachloride. The color intensity is proportional to the concentration of 0,0-dimethyl dithiophosphoric acid and is measured colorimetrically at 418 mμ, the absorption peak. The corresponding amount of insecticide is then ascertained by comparison with a standard curve prepared from known amounts of purified insecticide carried through the procedure." Preliminary tests with this method have shown it to be very accurate in recovering the toxicant from dust. None of the check plants produced the yellow color specified in this method.

The rainfall during the period from insecticide application to sampling was figured from records of official stations at or near the areas where the crops were grown.

RESULTS.—*Benzene hexachloride residues on clover from wettable powder sprays.*

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Table 1.—Benzene hexachloride recovered on clover sprayed with wettable powder by power sprayer.

Treatments Per Acre	Dates		Time—Treatment to Harvest	Rain, Inches	Benzene Hexachloride PPM
	Treated	Harvested			
			Hrs.		
Lindane W.P. 0.5 lb. gamma isomer	4/30	4/30	2	None	31.3
			Days		
	4/30	5/4	5	0.2	9.4
	4/30	5/15	16	1.1	0.8
	4/30	6/7	38	4.8	0.0
Lindane W.P. 0.25 lb. gamma isomer	4/30	5/4	5	0.2	1.8
	4/30	5/15	16	1.1	0.9
	4/30	6/7	38	4.8	0.0
Crude benzene hexachloride W.P. 4 lb. 0.24 lb gamma isomer	4/30	5/4	5	0.2	21.6
	4/30	5/15	16	1.1	3.7
	4/30	6/7	38	4.8	1.0

—Several field plots of approximately 2 acres each on the Amerman farm infested with the spittle bug, *Philaenus spumarius.* Linn. were sprayed April 30 with the following concentrations of ben ene hexachloride: 0.5 and 0.25 lbs. lindane per acre 4 lbs. of 50 per cent wettable crude benzene hexachloride containing 6 per cent gamma isomer, equalling 0.24 lb. gamma isomer per acre. A power sprayer adjusted to deliver about 50 gallons of spray per acre was employed. These insecticide applications gave excellent control of spittle bug and resulted in an increase in forage yields of approximately 30 per cent more than the untreated check areas. Representative samples were collected for analysis, 2 hours, and 5, 16, and 38 days after application. The last date corresponded with the time of the first commercial harvest on that farm. During this period plant growth was very rapid, increasing from 6 inches at time of treatment to about 23 inches in height at time of harvest. The results, presented in table 1, show a rapid decrease of BHC residues from all treatments. At harvest, on June 7, after accumulated total rainfall of 4.8 inches, no BHC was found in the lindane treated plots (Table 1) and only 1 PPM on the crop receiving crude BHC. The residues on the plot from crude BHC were higher at each analysis than from the lindane plots, as should be expected, since the crude material contains other BHC isomers and chlorinated hydrocarbons in addition to the gamma isomer. How much of the decrease in residue at harvest can be ascribed to any one of the following three factors: increase in plant growth, chemical decomposition, or wash off by rainfall, cannot be estimated with any reasonable degree of accuracy. All of these factors played their parts in virtually eliminating toxicant residues at harvest.

BHC emulsion sprays.—Plots of approximately 2.5 acres on the Phillips farm were sprayed by a low volume sprayer on April 30 with lindane emulsion at

Table 2.—Benzene hexachloride recovered on clover sprayed with Lindane emulsion.

Treatment Per Acre	Dates		Time, Treatment to Harvest	Rain, Inches	BHC PPM
	Treated	Harvested			
			Days		
0.2 lb. gamma isomer	4/30	5/4	5	0.2	3.8
	4/30	5/15	16	0.9	2.0
	4/30	6/18	49	6.1	0.0
0.4 lb. gamma isomer	4/30	5/4	5	0.2	3.8
	4/30	5/15	16	0.9	0.0
	4/30	6/18	49	6.1	0.0

Table 3.—Recovery of aldrin, dieldrin, lindane and toxaphene on alfalfa dusted with 40 lbs. per acre.

Treatment (per Acre)	Dates		Time from Treatment to Harvest	Rain, Inches	Toxicant PPM
	Treated	Harvested			
			days		
2.5% dust 1.0 lb. Aldrin	4/23	6/11	49	7.5	0.3
3% dust 1.2 lbs. Dieldrin	4/23	6/11	49	7.5	0.0
0.5% dust 0.2 lb. Lindane	4/23	6/11	49	7.5	0.0
5% dust 2 lbs. Toxaphene	4/23	6/11	49	7.5	0.0

Table 4.—Recovery of Insecticide 4049 from dusted corn and sprayed onions.

Treatments (per Acre)	Dates		Time from Treatment to Harvest	Rain, Inches	4049 PPM
	Treated	Harvested			
			days		
Corn					
2% dust	6/12				
0.8 lbs. 4049	6/16				
Stalks	6/24				
Husks	6/26	7/17	21	2.5	0.0
Kernels	6/26	7/17	21	2.5	0.0
	6/26	7/17	21	2.5	0.0
4% dust	6/12				
1.6 lbs. 4049	6/16				
Stalks	6/24				
Husks	6/26	7/17	21	2.5	0.0
Kernels	6/26	7/17	21	2.5	0.0
	6/26	7/17	21	2.5	0.0
Onions					
1 qt. 50% emulsion in 60 gal. 1.25 lb. of 4049					
Tops	7/7	7/18	11	0.7	0.0
Onions-unpeeled	7/7	7/18	11	0.7	0.0
Onions-peeled	7/7	7/18	11	0.7	0.0

concentrations of 0.2 and 0.4 lbs. per acre. The emulsions were applied at 40 lbs. pressure at rates varying from 25 to 40 gallons of spray per acre for the above two concentrations respectively. These applications gave excellent control of a spittle bug infestation, which ranged from 200 to 600 nymphs per square foot, and forage yields in the treated area were increased 89 per cent over those in the untreated check area. Samples were collected May 4 and 15 and at harvest on June 18. The results of the chemical analyses, summarized in table 2 show no residues at harvest after 6.1 inches of rainfall.

TOXICANT RESIDUES ON ALFALFA.—Plots, ranging from 1 to 3 acres on the Atkinson farm were dusted April 23 with the following insecticides: 5 per cent toxaphene, 2.5 per cent aldrin, 3 per cent dieldrin, and 0.5 per cent lindane to determine their efficiency in controlling spittle bug and pea aphid, *Illinoia pisi*. The applications were made by power duster at 40 lbs. per acre. At these concentrations, the actual amounts of toxicant deposited per acre on alfalfa were approximately 2 lbs. toxaphene; 0.2 lb. lindane; 1 lb. aldrin, and 1.2 lbs. dieldrin. Samples were collected at harvest 49 days after treatment. The cumulative amount of rainfall was 7.5 inches. Chemical analyses (table 3) revealed no residues of dieldrin, lindane and toxaphene, and only 0.3 PPM of aldrin.

Table 5.—Recovery of Insecticide 4049 from hand dusted lima bean plants.

Treatments (per Acre)	Dates		Time from Treatment to Harvest	Rain, Inches	4049 PPM
	Treated	Harvested			
2% dust	8/6	8/6	1 hour	None	74.0
0.8 lb 4049	8/6	8/7	1 day	0.05	18.0
	8/6	8/8	2 days	0.05	0.0
4% dust	8/6	8/6	1 hour	None	94.4
1.6 lbs. 4049	8/6	8/7	1 day	0.05	22.7
	8/6	8/8	2 days	0.05	1.0

Insecticide 4049 on corn.—Four replicated plots of sweet corn, 4 rows wide by 50 feet long, on the Bonnewitz Farm were dusted four times with 2 per cent and 4 per cent of 4049 against corn borer on the following dates: June 12, 16, 24 and 26, and were harvested July 17. The dusts were applied at the rate of 40 pounds per acre, giving 0.8 and 1.6 lbs. of actual toxicant per acre for the two concentrations respectively. Separate analyses were made of the stalks, husks, and grain. Prior to extraction, the grain were thoroughly disintegrated in a Waring blendor to determine any possible translocation of the toxicants. The chemical analyses (Table 4) did not detect the presence of toxicant residues in any one of the samples.

Insecticide 4049 on onions.—Onion plants were sprayed against thrips on July 7 on the Szmuds farm at the rate of one quart of 50 per cent 4049 emulsion in 60 gallons of water per acre, equalling 1.25 lbs. of toxicant. The crop was harvested July 18 and separate analyses were made of tops, unpeeled onions and peeled onions macerated in Waring blendor. As in the corn crop, no toxicant was recovered (table 4) from the plant, either as residue or by translocation, 11 days after treatment.

Table 6.—Recovery of 4049 from dusted lettuce, applied by power duster at 20 lbs. per acre.

Treatments (per Acre)	Dates		Time from Treatment to Harvest	Rain, Inches	PPM
	Treated	Harvested			
2% dust	9/17	9/17	4 hours	None	14.1
0.4 lb. of 4049	9/16	9/17	1 day	None	4.4
	9/17	9/19	2 days	None	1.7
	9/16	9/19	3 days	None	1.0

Rate of decomposition of 4049.—Since 4049 is somewhat similar in its chemical composition to parathion, which was shown to disappear rapidly from spray residues, Ginsburg, *et al.* (1950), Filmer, *et al.* (1951), it became of interest to determine the rate of decomposition of this newer phosphorus compound from dusted plants. For this purpose dusts containing 2 per cent and 4 per cent of 4049 were applied by hand duster at 40 lbs. per acre on lima bean plants at the college farm. Samples were analyzed immediately after application and 1 day and 2 days later. The results, given in table 5, indicate that the initial deposits of 74 PPM from the 2 per cent dust were reduced to 18 PPM after 1 day and none was recovered 2 days after application. From the 4 per cent dust the initial residue of 94.4 was reduced to 22.7 in 1 day, and to 1.0 PPM in 2 days after application.

Another experiment was conducted on lettuce. A dust of 2 per cent 4049 was applied by power duster at 20 lbs. per acre. Samples were collected for analyses 4 hours, 1 day, 2 and 3 days after treatment. The results presented in table 6, show that the initial residue of 14.1 PPM was reduced to 4.4, 1.7 and 1 PPM respectively. It becomes evident from these chemical analyses that insecticide 4049 rapidly decomposes on treated crops, almost completely disappearing within 3 days after application.

Insecticide 4049 at concentrations of 2 to 4 per cent gave some control for corn borer but was not so effective as parathion, DDT or Ryania. Fair control was obtained on onion thrips with 1 quart of 50 per emulsion concentrate per acre. On mexican bean bettle, *Epilachna corrupta*, Muls 4049 (2 to 4 per cent) appeared to be as effective as parathion.

SUMMARY AND CONCLUSIONS.—Chemical analyses were made of benzene hexachloride, aldrin, dieldrin and toxaphene residues on alfalfa and clover, sprayed or dusted in field experiments to control spittle bug, *Philaenus spumarius*. A study was also made on the rate of decomposition of residues from insecticide 4049 (S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate) on dusted corn and sprayed onions. The results brought out the following information:

1. No toxicant residues were recovered at harvest on clover and alfalfa either dusted or sprayed with lindane, applied at 0.2 to 0.5 lb. per acre.

2. The residues from crude benzene hexachloride on clover, sprayed with 4 lbs. of 50 per cent wettable powder per acre, were considerably higher than from lindane analyzed at three different intervals between application and harvest, but only 1 PPM was found at final harvest, 38 days after application.

3. No residues were recovered on alfalfa dusted once with lindane, dieldrin, toxaphene, and only 0.3 PPM of aldrin, 49 days after application.

4. No residues were recovered about 21 days after the last application from corn dusted four times with either 2 per cent or 4 per cent of 4049. Likewise, no tocicant was recovered on onions sprayed once with a 50 per cent emulsion at the rate of 1.25 lbs. of 4049 per acre.

5. The insecticide 4049 undergoes rapid decomposition on plants, leaving practically no residue 3 days after application.

6. The BHC insecticides gave excellent control of the spittle bug, *Philaenus spumarius*, Linn. resulting in substantial increases of forage yields over the untreated check areas.

7. Insecticide 4049 gave good control of mexican bean beetle, *Epilachna corrupta*, Muls., fair control of onion thrips, *Thrips tabaci*, Lind. and some control of corn borer, *Pyrausta nubilalis*, Hubn.

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Controlling Curly Top Virus in Agricultural Crops by Reducing Populations of Overwintering Beet Leafhoppers

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One of the most important and possibly the most difficult problems with which growers of susceptible crops have to contend in California is that of controlling curly top virus or Western yellow blight as it is often called when associated with tomatoes. In the absence of control this disease has been responsible for serious annual losses to growers of tomatoes, melons, cucumbers, beans, and spinach, which are planted in considerable acreage in the area in which the problem is critical. Even resistant varieties of sugar beets, as developed in recent years, can suffer severely in seasons of high virulence. Growing of melons and cucumbers in some areas highly adaptable to their culture has had to be discontinued due to the prevalence of this virus. Tomatoes, particularly the early table varieties, have suffered most, losses to individual growers running up to one hundred per cent in large plantings, while the expected average loss has ranged from ten to twenty per cent.

The sugar beet leafhopper, *Circulifer tenellus*, is the only known vector of this disease and effective control of the latter seems to lie in the degree to which their numbers can be reduced in certain foothill areas where they winter, prior to their spring movement back into the cultivated areas on the floor of the valley.

The beet leafhopper is common to the semi-arid areas of the southwestern United States but nowhere does it seem to present the economic problem which it does in the San Joaquin Valley in California. This, undoubtedly, is due to the tremendous acreage of highly susceptible crops grown in close proximity to exceptionally favorable over-wintering quarters. The over-wintering area is roughly two hundred and fifty miles long by twenty miles wide lying along the western side of the valley between the San Francisco Bay region on the north and the Tehachapi Mountains on the south.

In general control as now practiced consists of spraying concentrations of leafhoppers as they occur in particular locations within the over-wintering area, selected on the basis of long experience. There are three separate periods, in the fall, winter, and spring when such spraying is done which fall between November 1 and April 20. The material used consists of DDT in diesel oil applied as an aerosol at the rate of 1 pound actual in 2 gallons of oil, per acre. It is applied by plane and by ground machine as conditions permit, the latter being of the turbine blower type. Control operations are obviously based on the life history and habits of the leafhopper as worked out for this particular area.

During the summer months the leafhoppers pass through three or more generations on agricultural crops and weed hosts on the floor of the valley. In late summer, as their hosts are harvested or dry up, a winter generation is formed, the adults of which move into the higher and drier foothills for the winter. Normally the winter hosts in the foothills have not developed at this time making it necessary that the leafhoppers hold over on certain perennial brush, mostly *Atriplex* spp., which is common to the alluvial fans extending out from the various canyons leading into the foothills. Their attraction to those perennials is apparently facilitated by the general trend of wind currents towards the canyons. The concentrations of leafhoppers resulting under those conditions can be effectively sprayed, reducing their numbers. These initial fall operations start about November 1 and may continue for approximately 6 weeks.

With the first winter rains in the foothills the winter hosts spring up and any remaining leafhoppers, including late arrivals, quickly move over onto the more attractive filaree, pepper grass, and plantago. Here they remain concentrated for a short time on the floor of the canyons, permitting their further reduction in numbers by spraying. These winter

spraying operations start about December 15, extending through to February 1.

Ultimately, the leafhoppers disperse so widely as to make further spraying impractical until they again concentrate on sparse growth on low knolls having a warm southerly exposure where they produce the spring, or flight, generation. During this period which lasts from about March 1 to April 20, their numbers can be still further reduced. Some time between April 15 and 20, practically without exception, the remaining females of this generation move, almost overnight, back into the cultivated areas on the floor of the valley, carrying the virus with then, and the completed cycle starts over. While the spring flight may take place to all parts of the compass it is usually to the north with the direction of the prevailing winds. These flights have been proven to have extended as far as 80 to 120 miles in a single night. Those cultivated hosts available at the time of the flight naturally bear the brunt of the initial attack. As the leafhoppers redistribute themselves over the floor of the valley the hazard of virus infection is proportionately reduced.

Movement of the leafhoppers into the foothills in the fall is progressive from north to south, and from the foothills in the spring is similarly progressive from south to north. Spray operations are timed accordingly. Obviously, in such an extended area it is possible to treat only the major or more critical concentrations. However, it has been learned by experience that, by these carefully times treatments, the number of leafhoppers can normally be reduced to a point where the survivors which find their way back into the cultivated areas cause little more than a minimum of crop damage.

Typical of the thousands of acres of Russian thistle sprayed as part of the beet leafhopper control program.

The time of and the impact resulting from the spring flight make it important that growers of susceptible crops delay planting as long as possible, preferably until after April 20. This is possible with most of the crops concerned excepting those varieties of table tomatoes which depend on early planting to meet a highly profitable early eastern market. For that reason the latter probably suffer more from the virus and the growers are more dependent for protection on high winter leafhopper kill than those of any other single crop.

The time and extent of winter rainfall can either adversely or favorably affect the control program. Early, light rains in the fall may develop the winter hosts before the summer hosts have dried up in which event the leafhoppers may move over and become immediately so widely dispersed as to preclude any effective fall or winter spraying. Late, scattered, spring showers may extend the life of the winter hosts to the point of permitting a second generation of leafhoppers in the

Tank trucks and trailers delivered spray materials to temporary flight strips and served as stand-by storage until emptied. Twelve thousand gallons pictured served two planes for ten hours flying time.

Light, scattered stands of thistle sprayed by ground machine using standard aerosol turbines covering a one-hundred foot swath.

	1951	1950	1949	1948	1947	1946	Five-Year Average
San Joaquin Valley							
Kern (late)	11.6	15.9	11.5	51.4	87.5	33.5	26.9
Tulare	8.1	84.5	23.7	1.3	8.9	26.	30.5
Fresno	5.1	77.5	49.4	4.7	61.4	16.8	42.9
Madera	5.5	69.5	67.3	.9	46.5	13.6	40.7
Merced	3.	44.5	39.2	81.3	34.3	6.	41.7
Stanislaus	2.4	7.1	20.5	1.8	6.6	2.	8.1
San Joaquin	1.5	7.3	6.4	.7	3.6	1.5	4.2
Average	5.2	43.8	31.2	20.3	35.5	14.2	27.9
Salinas Valley							
Monterey	2.3	31.1	34.7	50.4	10.5	7.9	26.9

FIG. 1.—Curly top virus. Per Cent infection in Tomato Plants

foothills, resulting in a number of small flights over a period of 6 weeks rather than a single mass flight. This situation could not only depreciate the value of the spring spraying but also seriously upset planting dates from the protective standpoint.

Heavy and extended winter rains can develop a luxurious stand of filaree, the existance of which is seriously adverse to the survival of the over-wintering leafhoppers—in fact, it can almost eliminate them. On the other hand, lack of rainfall is favorable to the leafhoppers and at the same time encourages the growth of extensive stands of Russian thistle which is a host both of the virus and of the leafhopper. Heavy rainfall favors other range plants which may crowd out the thistle.

Both the control and the crop areas are areas of winter rainfall. In the northern half of the control area the average annual rainfall is around 8 to 12 inches; in the southern half it is less than 4 inches. In the agricultural areas concerned it ranges from 6 to 18 inches.

Due to the series of years of below normal rainfall which are being experienced in the sothern half of the control area, a new factor has been injected into the control program. This condition has been conducive to the growth of hundreds of thousands of acres of heavy stands of Russian thistle on the open range land lying between the agricultural areas and the foothills. This thistle in turn has been responsible for the production of epidemic populations of leafhoppers by fall. Unless these numbers are reduced materially before they escape to the foothills the winter control problem is magnified beyond practical limits. Such reduction is difficult, not because of the acreage involved, but because of the time limit imposed. Not more than 20 days is allowed, closely following October 1, in which effective spraying can be accomplished. Spraying must be delayed until the maximum number of eggs responsible for the winter generation have hatched, and yet not delayed to a point permitting any appreciable number of adults escaping to the foothills. In meeting this problem in the fall of 1950, a total of 564,000 gallons of spray was applied to 141,000 acres of Russian thistle including all contiguous solid stands. Application was by plane at the rate of 4 gallons per acre, made between October 1 and November 1. Favorable climatic conditions permitted the longer period. The degree of control obtained as evidenced by the almost total absence of virus in tomatoes in 1951 was phenomenal. In the fall of 1951, a total of 150,000 acres of thistle was again sprayed between October 5 and 15, using 300,000 gallons of material. In 1951 the amount of DDT used was reduced from 1.5 pounds actual to 1 pound per acre and the amount of oil from 4 gallons to 2 gallons per acre, as used the preceding season. Also, the material was flown at 25 feet in 1951 with a 100-foot swath in place of thistletop level with a 50-foot swath, as in the preceding year. These changes were based on findings made by Chamberlin[1] at Forest Grove, Oregon, and Douglass[2], Twin

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Falls, Idaho. The results were comparable with those of 1950.

By legislative commitment made at the request of industry the State Department of Agriculture has been given full responsibility for carrying out this control program with adequate appropriations for its conduct. The basic reason for the state being engaged in a continuing insect pest control program of this nature is that it lies on open range land given over to sheep raising which belongs principally to non-resident owners having no direct interest in the problem. In fact, the real problem is one of public relations in securing their friendly cooperation in permitting the necessary spraying which they consider, if not a direct hazard, is at least a serious inconvenience to their own interests. Any private agency would find it difficult, if not impossible to operate effectively under such conditions and over such an extended area.

In evaluating the results obtained from the control program outlined it has been necessary to use the incidence of disease as expressed in tomatoes at the peak period each season, as a yardstick. It not only represents the most widely planted host within the area being protected but is also the most susceptible to the virus. Normally the incidence of the virus in tomatoes in those areas which are considered critical but have not come under the influence of the control operations ranges from 36 per cent to 100 per cent each season. In similar areas considered as being protected by these measures the incidence of disease has ranged from zero to 30 per cent. In the spring of 1950 prior to any attempt to control the epidemic population of leafhopper that was developing on Russian thistle, losses to growers of early table tomatoes in certain areas were close to 100 per cent and ran into several million dollars. In the same critical area in 1951 following the extensive emergency spraying of thistle the preceding fall, the average incidence of disease was well below 10 per cent with a full crop being harvested. The latter was possible due to the fact that the appearance of any disease in these plantings occurred so late as not to affect the production of diseased vines. The over-all incidence of disease in late canning varieties was less than 1 per cent against a normal expectancy of 20 per cent.

The annual legislative appropriation for fall, winter, and spring spraying averages $100,000. The emergency spraying of Russian thistle in October in 1950 and again in 1951 has required an additional $250,000 each season. The need for this latter amount will apparently continue as long as the present stand of thistle persists. Its persistence in years of deficient rainfall is fortunate as it is the only plant which survives such conditions in sufficient stand to prevent serious wind erosion. During wet years it will be naturally replaced by plants less favorable as hosts of the virus disease or the leafhoppers and the control problem correspondingly reduced.

While a third of a million dollars may in the aggregate seem to be a considerable amount of money for a single agency to expend annually in a single insect control project, it actually represents less than one-half of one per cent of the average annual return to the growers of the crops being protected.

Control operations from the State's standpoint cease with the spring flight as far as spraying is concerned and the problem, such as it is, becomes one of individual grower control on cultivated crops during the summer months. In general, late planting and in some instances spraying of attractive weed hosts around the margins of fields with 5 per cent DDT, or of such weeds within plantings prior to cultivation, or of the host crop itself, will give protection against the minimum numbers of leafhoppers that escape the winter operations.

DR. MARCOVITCH ON LEAVE IN ISRAEL

Dr. S. Marcovitch of the Tennessee Agricultural Experiment Station left on July 9, 1952 for Israel, where he expects to spend the next year on a Point 4 program. He may be addressed c/o J. Peleg, Box 8393, Jaffa, Israel.

Experimental Control of Plum Curculio on Peaches

ROY W. RINGS, *Ohio Agricultural Experiment Station, Wooster*[1]

The plum curculio, *Conotrachelus nenuphar* (Hbst.), has recently become the most important insect enemy of the peach in Ohio. While remedial measures for the control of the oriental fruit moth attracted the attention of entomologists over a period of nearly 20 years, the damage caused by the fruit moth in the past four years has been far exceeded by that of the curculio.

The experimental program during the past 6 years has been devoted largely to the evaluation of new insecticides for the control of plum curculio infesting peaches and plums. The results of investigations conducted on plums have been reported previously by Neiswander (1948) and Rings (1951). The results of investigations conducted on peaches in 1946 and 1947 have been presented by Neiswander (1948) while the present paper deals with information obtained from 1948 to 1951.

METHODS.—Field investigations were conducted in three orchards in Ottawa County, two of which were located at the Luchsinger Fruit Farm while one was located at the East Harbor State Park. These orchards were divided into from 32 to 50 plots, each of which contained four trees in the form of a square. Plots were separated by an intervening row of unsprayed trees to reduce effects of spray drift and to minimize the movement of beetles from one treatment plot to another Each of the experimental treatments was replicated four to five times and the plot replicates were selected at random.

Spraying was begun in the spring at the shuck-split stage except in 1948 when applications were begun at petal-fall. The control schedule consisted of three applications of each treatment made at 10-day intervals. The sprays were applied with a conventional high-pressure hydraulic sprayer using a single-nozzle spray gun. Applications were made from the ground walking around the trees in an attempt to secure adequate and thorough coverage of all parts of the tree. Microfine dry wettable sulfur was included in each treatment for the control of brown rot. Good coverage of the trees was obtained with approximately three gallons of spray at shuck-split. As the season progressed it became necessary to increase this amount to as much as 5 gallons per tree.

Field treatments were evaluated by determining the relative differences in populations of adults, in larval populations, in the degree of protection afforded the peach crop and in the degree of drop fruit infestation.

Adult populations were determined by jarring individual trees vigorously over a 9 by 9 foot unbleached muslin sheet. Each of the sprayed trees was jarred at frequent intervals throughout the season.

Larval populations were determined by collecting drop fruits at 5-day intervals from beneath sprayed trees. The drops were labeled and transported to Wooster where they were transferred to mesh vegetable bags. Galvanized iron buckets were placed beneath the bags to collect the larvae as they deserted the fruit. Daily records were kept of larval emergence from each plot. The degree of drop fruit infestation was calculated from the total number of drops and the total number of larvae reared from each treatment.

Records were also taken on the amount of injury caused to the peach crop by the mature insects in feeding and ovipositional activities. In pre-harvest examinations the fruit was examined on the trees and additional injury records were obtained at harvest. This technique proved to be the least reliable of those used in evaluation procedures because of the difficulty in identifying certain types of curculio injury.

The laboratory tests were conducted in accordance with methods previously described (Rings 1950). This method consists of simply immersing the terminal

[1] Acknowledgment is made to Dr. W. A. Gould, Department of Horticulture, Ohio State University, for the flavor evaluations, to Mr. J. E. Fahey, Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, for the insecticidal analyses and to L. D. Luchsinger of the Luchsinger Fruit Farm and A. E. Day, Superintendent of Parks, Ohio Department of Natural Resources, for providing facilities for these investigations. Thanks are also due James S. Bowman, Charles Gerber, George W. Layne, Jr., Alan L. Steffen, David Walther and Andrew A. Weaver for their assistance in obtaining records.

shoots of peach in aqueous suspensions of the various insecticides. After the shoots have dried thoroughly they are exposed to summer-brood adults in small cages or in battery jars. Observations on knockdown are made at frequent intervals. These tests serve to screen new materials and also provide further information to supplement that obtained in field experiments.

In 1948 a cooperative project dealing with the effect of insecticides upon the flavor of processed fruits and vegetables was established in conjunction with the Department of Horticulture at The Ohio Ohio State University. Through this project it has been possible to secure information on the effect of insecticides upon the quality of processed peaches.

Samples of the fruit for taste tests were selected at harvest on the basis of uniformity in ripeness and freedom from insect injury. Although the sampling could not be strictly randomized, it was representative of the different areas of the individual trees and of the orchard. These samples were coded and delivered to the University Horticultural Products Laboratory. Here they were prepared for canning and subsequently processed according to acceptable commercial standards. After processing, the canned samples were stored at room temperatures for a period of 3 months prior to flavor evaluations.

The taste panel used to evaluate these samples was composed of students and faculty members of the Departments of Horticulture and Home Economics. Panel members worked individually in booths and scored samples from "1" to "10". A score of "1" was unsatisfactory and a score of "10" represented unmodified flavor. Samples treated with lead arsenate were used as a standard although the identity of this sample was unknown to judges at the time of tasting. A sample was considered to be off-flavor if the sample mean was significantly different from the standard mean at the 1 per cent level.

MATERIALS.—The following insecticides were used in the control investigations:

(1) Lead arsenate (acid)
(2) Benzene hexachloride
(3) Lindane
(4) Chlordane
(5) Toxaphene
(6) Methoxychlor
(7) Aldrin
(8) Dieldrin
(9) Parathion
(10) DDT
(11) Heptachlor
(12) Tetraethyl pyrophosphate (TEPP)
(13) Ethyl p-nitrophenyl thionobenzenephosphonate (EPN)[2]
(14) Ethyl o-nitrophenyl thionobenzenephosphonate (EON)[2]
(15) 2-nitro-1,1-bis(p-chlorophenyl) propane (Compound 645A)[3]
(16) 2-nitro-1,1-bis(p-chlorophenyl) butane (Compound 728)[3]
(17) 8.33 per cent 2-nitro-1,1-bis(p-chlorophenyl) propane and 16.67 per cent 2-nitro-1,1-bis(p-chlorophenyl) butane (Compound 645A +728)[3]
(18) S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (Compound 4049)[4]
(19) Octamethyl pyrophosphoramide (STM-1)[5]
(20) A trialkyl thiophosphate (STM-2)[6]
(21) Diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin (Compound E838)[7]
(22) 1,1-bis(p-ethyl phenyl) 2,2-dichloroethane (Compound Q-137)[8]

PROCEDURES.—In 1948 benzene hexachloride, lindane, chlordane, parathion and toxaphene were compared with lead arsenate for the control of plum curculio infesting Zarn peaches. All of the formulations employed were wettable powders. The strength of the formulations, the dosages used and the evaluation data appear in table 1. Three spray applications were made and were designated as petal-fall, shuck-split and first cover. The respective dates of application were May 8, 18 and 28.

Table 1.—Effectiveness of organic insecticides against plum curculio in 1948. (Zarn peaches, Luchsinger Fruit Farm, Gypsum, Ohio.)

TREATMENT	DOSAGE Lbs. per 100 Gals.	MEAN NO. LARVAE PER PLOT	PER CENT DROPS INFESTED	PER CENT REDUCTION OF LARVAE
1. BHC 6% γ	3	8.8	12.7	24.1
2. Lindane 25% γ	1	6.8	9.4	41.4
3. Chlordane 40% (A)	2.5	4.4	6.4	62.1
4. Toxaphene 25%	4	40.4	22.2	0
5. Parathion 25%	2	2.8	3.7	75.9
6. Lead arsenate	2	11.6	26.3	0
Zinc sulfate	4			
Hydrated lime	6			

In 1949 field tests were conducted in a block of Elberta and Welcome peaches

[2] E. I. du Pont de Nemours and Company.
[3] Commercial Solvents Corporation.
[4] American Cyanamid Company.
[5] Pestox 3, Dow Chemical Company.
[6] Systox, Pittsburgh Agricultural Chemical Company.
[7] Potasan, Pittsburgh Agricultural Chemical Company.
[8] Rohm and Haas Company.

bordering a woods. Although indications in 1948 pointed to a heavy infestation the following year only a light infestation was present and no significant differences were obtained between the insecticides being compared. This series of plots, however, provided samples for taste panel evaluation.

Preliminary screening tests were conducted during the summer of 1949 to provide candidate materials for field tests in 1950. For convenience the screening tests are combined with the 1950 field data in table 2. In these tests aldrin, benzene hexachloride, chlordane, Compound 645A, DDT, dieldrin, EON, EPN, heptachlor, lindane, methoxychlor, parathion, toxaphene and TEPP were evaluated for knockdown speed in cage tests. As a result of the screening tests three new materials, aldrin, dieldrin and EPN, were initially field tested in 1950. These materials were compared with parathion, chlordane, benzene hexachloride and methoxychlor for the control of plum curculio infesting Elberta peaches. Three spray applications of each treatment were designated as shuck-split, first and second cover spray and were applied on May 22, June 1 and June 10. Table 2 presents a summary of the field evaluation data.

In August 1950 preliminary screening tests with 16 insecticides, including 7 new synthetic organic compounds, were conducted with summer-brood adults. The results of these tests in terms of speed of knockdown are recorded in table 3. These tests revealed that two new candidate materials, Compound 4049 and STM-2, possessed considerable toxicity to curculio under cage test conditions. These materials were then compared with aldrin, benzene hexachloride, dieldrin, EPN, heptachlor, methoxychlor and parathion for the control of plum curculio under field conditions. The applications of each treatment were, shuck-split on May 23, first cover on June 1 and second cover on June 11.

RESULTS.—*Lead arsenate.* This material used at the rate of 2 pounds in 100 gallons of water was selected as a standard when field tests were conducted in commercial orchards in 1948 and 1949. Since it was not practical to leave unsprayed plots in these orchards, it was impossible to determine the degree of control attained with lead arsenate. In the 1948 tests (Table 1) it was indicated

Table 2.—Effectiveness of organic insecticides against plum curculio in 1950. (Elberta peaches, East Harbor State Park.)

Treatment	Dosage	Laboratory Tests	Field Tests			
	Lbs. per 100 Gals.	Hours Required for 100% Knockdown	Mean No. Beetles per Plot	Per Cent of Fruit Injured by Curculio	Mean No. Larvae per Plot	Per Cent Reduction of Larvae
1. Aldrin 25%	1	12	8.8	7.5	28.0	83.0
2. BHC 10% γ	2.5	120+	19.2	7.7	9.2	95.7
3. Chlordane 50% (A)	2	9				
4. Chlordane 50% (B)	2		9.3	12.7	58.8	64.2
5. Compound 645A 50%	1	74				
6. Compound 645A 50%	2	48				
7. DDT 50%	2	120+				
8. Dieldrin 15%	1.5	9	8.0	7.0	3.2	98.6
9. EON 35%	2	12				
10. EPN 25%	1	24				
11. EPN 25%	2	9				
12. EPN 25%	1.5		7.3	4.5	35.2	78.6
13. Heptachlor 25%	4	9				
14. Lindane 12% γ	2	120+				
15. Methoxychlor 50%	2	120+	8.3	6.3	30.8	81.4
16. Parathion 25%	1	9				
17. Parathion 25%	2	6				
18. Parathion 15%	2		7.5	7.5	40.8	73.6
19. Toxaphene 25%	4	97				
20. TEPP 40%	1	24				
21. Control		120+	35.7	31.3	165.2	—

Table 3.—Effectiveness of organic insecticides against plum curculio in 1951. (Elberta peaches, East Harbor State Park.)

Treatment	Dosage	Laboratory Tests	Field Tests		
	Lbs. per 100 Gals.	Hours Required for 100% Knockdown	Per Cent of Fruit Injured by Curculio	Mean No. Larvae per Plot	Per Cent Reduction of Larvae
1. Aldrin 25%	1	30	7.4	5.0	85.5
2. BHC 10% γ	2.5	132+	2.8	.7	97.9
3. Chlordane 50% (B)	2	78			
4. Compound 4049 50%	2	24			
5. Compound 4049 25%	3		2.5	27.0	24.6
6. Compound 4049 50%	4	9			
7. Compound 728 25%	4	132+			
8. Compound 728 25%	8	132+			
9. Dieldrin 15%	1.6	18			
10. Dieldrin 25%	1		7.7	2.5	92.8
11. Compound 645A+728 25%	4	84			
12. Compound 645A+728 25%	8	96			
13. EPN 25%	1.5		4.2	2.0	94.2
14. EPN 25%	2	18			
15. Heptachlor 25%	4	18	3.7	1.5	95.7
16. Lead arsenate	2	132+			
17. Methoxychlor 50%	2	132+	5.0	4.5	87.0
18. Parathion 15%	2	18	3.7	5.5	84.1
19. STM-1 40%	2	132+			
20. Compound E838 31%	1	132+			
21. Compound Q-137 50%	1	84			
22. Compound Q-137 50%	2	48			
23. STM-2 32%[1]	2	132+	6.9	11.7	56.5
24. Control		132+	9.2	34.5	—

[1] STM-2 killed only 15 per cent of the beetles in 132 hours by contact action but killed 100 per cent in 36 hours by systemic action.

that lead arsenate afforded more protection than some of the candidate materials. In four cage tests lead arsenate acted very slowly and killed no more than 20 per cent of the beetles in 6 days.

Benzene hexachloride. This material was used at the rate of 0.18 pound of gamma isomer in 100 gallons in 1948 but because of its poor performance the concentration was increased to 0.25 pound of gamma isomer in later tests. In cage tests some beetles knocked down by benzene hexachloride would later recover and appear perfectly normal. In five cage tests from 10 to 85 per cent of the beetles were knocked down in 132 hours. In field tests benzene hexachloride gave only a fair degree of control when three applications of a spray made up of 3 pounds of a 6 per cent gamma isomer formulation were made to Zarn peaches (Table 1). When this amount was increased to 3 applications of a spray containing 2.5 pounds of a 10 per cent gamma isomer, excellent control of plum curculio larvae was obtained (Tables 2 and 3).

An experiment conducted in 1948 clearly indicated that benzene hexachloride produced off-flavors in peaches if more than two sprays were used. In this test Elberta peaches were sprayed 2, 3, 4 and 5 times with a spray consisting of 1.5 pounds of a benzene hexachloride wettable powder carrying 12 per cent of the gamma isomer (Treatments 2, 3, 4 and 5, Table 4). Flavor evaluations which were later made on the fruit after processing showed that there was a direct correlation between the number of sprays applied and the degree of mustiness detectable in the fruit. Three of the five samples of Halehaven fruit sprayed with technical benzene hexachloride 87 days before harvest showed significant off-flavor (Table 4). Off-flavors were detectable in two fruit samples which were sprayed with high gamma benzene hexachloride. The high gamma material was prepared from a 97 to 98 per cent gamma benzene hexachloride and did not meet the specifications for lindane (Table 4).

Lindane. Several formulations of this material have been employed in field

Table 4.—Effect of benzene hexachloride and lindane applications upon flavor of processed peaches. 1948.

Treatment	Dosage: Lbs. per 100 Gals.	Variety[1]	Application Dates	Harvest Date	Days—Last Application to Harvest	Average Rating of Fruit Flavor
1. Control		E		9-4		8.9
2. BHC 12% γ	1.5	E	5-5, 5-19	9-4	104	7.1
3. BHC 12% γ	1.5	E	5-5, 5-19, 6-18	9-4	78	4.7[3]
4. BHC 12% γ	1.5	E	5-5, 5-19, 6-18	9-4	52	4.1[3]
5. BHC 12% γ	1.5	E	5-5, 5-19, 6-18, 7-14	9-4	21	2.9[3]
Least significant difference at 1% level						2.1
6. Control		HH		8-23		9.7
7. BHC 6% γ	3	HH	5-4, 5-18, 5-28	8-23	87	7.7[3]
8. BHC 6% γ	3	HH	5-4, 5-18, 5-28	8-23	87	8.7
9. BHC 6% γ	3	HH	5-4, 5-18, 5-28	8-23	87	7.0[3]
10. BHC 12% γ	1.5	HH	5-4, 5-18, 5-28	8-23	87	9.0
11. BHC 12% γ	1.5	HH	5-4, 5-18, 5-28	8-23	87	7.6[3]
12. BHC 25% high γ	1	HH	5-4, 5-18, 5-28	8-23	87	6.3[3]
13. BHC 25% high γ	1	HH	5-4, 5-18, 5-28	8-23	87	7.8[3]
14. Lindane 50% γ	0.5	HH	5-4, 5-18, 5-28	8-23	87	6.9[2,3]
15. Lindane 50% γ	0.5	HH	5-4, 5-18, 5-28	8-23	87	7.9[3]
16. Lindane 50% γ	0.5	HH	5-4, 5-18, 5-28	8-23	87	8.3[3]
Least significant difference at 1% level						1.4

[1] Varietal abbreviations are: E, Elberta; HH, Halehaven.
[2] Polyethylene polysulfide included in spray.
[3] Flavor significantly poorer than untreated check at 1 per cent level.

investigations and in flavor evaluation tests. In 1948, 8 ounces of a lindane wettable powder carrying 50 per cent gamma isomer was tested on Redhaven, Golden Jubilee and Halehaven peaches. In 1949, 2 pounds of a lindane wettable powder carrying 12 per cent gamma isomer were tested on Elberta and Welcome peaches.

Lindane caused off-flavor in peaches when applied in combination with micronized sulfur and when it was applied in combination with micronized sulfur and polyethylene polysulfide the off-flavors were accentuated. Off-flavors were not detectable in Elberta peaches sprayed with lindane four times with the last application made 88 days before harvest (Table 6).

Chlordane. Three formulations of chlordane were employed during the course of these investigations. Chlordane (A) at 40 and 50 per cent strengths was furnished by one manufacturer in 1948 and in 1949 while another manufacturer furnished chlordane (B), a 50 per cent wettable powder, in 1950. This material was used at the rate of 1 pound actual toxicant in 100 gallons in all experiments.

Experimental results in 1948 with chlordane (A) indicated that this material was superior to both lead arsenate and technical benzene hexachloride at the concentrations employed (Table 1). In these tests chlordane gave control equivalent to lindane at the rate of 4 ounces of gamma isomer.

Chlordane (A) gave excellent results in 1949 cage tests and knocked down 100 per cent of the beetles in 9 hours (Table 2). In 1950 chlordane (B) required 78 hours to knock down 100 per cent of the beetles (Table 3) and the field results with this material were very poor (Table 2). Later a direct comparison of the two materials in cage tests showed that chlordane (A) was much superior to chlordane (B) in toxicity to adult curculios. For this reason chlordane (B) was omitted from the 1951 field tests. Three applications of chlordane to Zarn peaches in 1948 (Table 5) and four applications of chlordane to Elberta peaches in 1949 (Table 6) did not produce off-flavor in canned fruit.

Toxaphene. The results obtained with this material for curculio control in 1948 were so poor that it was not tested further

Table 5.—Effect of insecticides upon flavor of processed Zarn peaches (1948).

Treatment	Dosage: Lbs. per 100 Gals	Dates of Application	Harvest Date	Days, Last Application to Harvest	Average Rating of Fruit Flavor
Parathion 25%	2	5-8, 5-18, 5-28	8-20	84	8.6
Lead arsenate	2	5-8, 5-18, 5-28	8-20	84	8.3
BHC 25% high γ	1	5-8, 5-18, 5-28	8-20	84	8.2
Chlordane 40%	2.5	5-8, 5-18, 5-28	8-20	84	8.2
Toxaphene 25%	4	5-8, 5-18, 5-28	8-20	84	8.2
BHC 25% high γ	1	5-18, 5-28, 6-9	8-20	84	8.1
Chlordane 40%	2.5	5-18, 5-28, 6-9	8-20	84	7.9
BHC 6% γ	3	5-8, 5-18, 5-28	8-20	84	5.8
Least significant difference at 1% level					1.6

(Table 1). In mixing toxaphene with wettable sulfur it was noted that the insecticide caused the flocculation of the fungicide. This reaction was avoided by adding 4 ounces of bone glue to 100 gallons of spray prior to adding the fungicide and insecticide. Toxaphene did not significantly impair the flavor of canned peaches (Table 5).

Methoxychlor. Methoxychlor was tested in five cage experiments and in three field experiments. One pound actual methoxychlor in 100 gallons of water was used in all tests. This material acted rather slowly in cage tests but death occurred soon after knockdown. Mortalities of 65, 85, 55 and 75 per cent were recorded in four tests after 6 days while in another test 100 per cent of the beetles were knocked down in 72 hours. Methoxychlor gave excellent control of the plum curculio infesting Elberta and Welcome peaches in two seasons of field trials (Tables 2 and 3). In 1950 the degree of control achieved with methoxychlor was exceeded only by that from dieldrin and EPN. Methoxychlor residues were very persistent as shown by the fact that an average residue of 6.8 parts per million of methoxychlor were present 37 days after the final application of a 3 application schedule. Tasters could detect no foreign flavor in Elberta peaches treated with three applications when the last application was made 83 days before harvest (Table 7).

Although methoxychlor presents almost no hazard to the user, it is ineffective against oriental fruit moth and, like DDT, has a tendency to permit increase of populations of orchard mites.

Aldrin. This material was found to be more toxic to summer brood adults than any of the chlorinated hydrocarbons except dieldrin and heptachlor. In one cage test 100 per cent of the beetles were

Table 6.—Effect of insecticides upon flavor of processed Elberta peaches (1949).

Treatment	Dosage: Lbs. per 100 Gals.	Dates of Application	Harvest Date	Days, Last Application to Harvest	Average Rating Fruit Flavor
Chlordane 50%	2	5-5, 5-15, 5-25, 6-6	9-2	88	8.7
Lindane 25% γ	1	5-5, 5-15, 5-25, 6-6	9-2	88	8.4
Parathion 25%	1	5-5, 5-15, 5-25, 6-6	9-2	88	8.2
Parathion 25%	2	5-5, 5-15, 5-25, 6-6	9-2	88	8.2
Lead arsenate plus DDT 50%	2	5-5, 5-15, 5-25, 6-6	9-2	88	8.2
Lindane 12% γ	2	5-5, 5-15, 5-25, 6-6	9-2	88	8.1
Control			9-2		7.7
BHC 10% γ	2.5	5-5, 5-15, 5-25, 6-6	9-2	88	6.7[1]
Least significant difference at 1% level					.8

[1] Flavor significantly poorer than untreated check at 1% level.

Table 7.—Effect of insecticides on flavor of processed Elberta peaches (1951).

Treatment	Dosage: Lbs. per 100 Gals.	Dates of Application	Harvest Date	Days, Last Application to Harvest	Average Rating of Fruit Flavor
STM-2 32%	1 qt.	5-22, 6-1, 6-10	9-1	83	8.2
Control			9-1		7.6
EPN 25%	1.5	5-22, 6-1, 6-10	9-1	83	7.6
Methoxychlor 50%	2	5-22, 6-1, 6-10	9-1	83	7.6
Heptachlor 25%	4	5-22, 6-1, 6-10	9-1	83	7.4
Parathion 15%	2	5-22, 6-1, 6-10	9-1	83	7.3
Dieldrin 25%	1	5-22, 6-1, 6-10	9-1	83	7.1
Aldrin 25%	1	5-22, 6-1, 6-10	9-1	83	6.6
BHC 10%	2.5	5-22, 6-1, 6-10	9-1	83	6.3
Compound 4049 25%	3	5-22, 6-1, 6-10	9-1	83	3.3[1]
Least significant difference at 1% level					1.8

[1] Flavor significantly poorer than untreated check at 1% level.

affected in 12 hours, in three others 24 hours were required while in a fifth test 36 hours were required. Beetles which were knocked down remained moribund for as long as 2 days and some moribund beetles later recovered. Aldrin gave very good control of curculio in both 1950 and 1951 tests (Tables 2 and 3) and was superior to benzene hexachloride and chlordane (B). Aldrin was used at the rate of 1 pound of a 25 per cent wettable powder in 100 gallons of water throughout these investigations. In the 1951 flavor evaluations aldrin did not produce off-flavor in canned Elberta peaches.

Dieldrin. In 1950 this material was used at the rate of 0.225 pound actual toxicant in 100 gallons while in 1951 it was used at the rate of 0.25 pound. The change was made because of the difference in formulation (Tables 2 and 3). Dieldrin proved to be very rapid in action against beetles in cage tests although the individuals remained moribund for several days. None of the 100 individuals employed in cage tests recovered after knockdown. In 1950 dieldrin gave a 77.6 per cent reduction in population of spring brood adults in field plots. Dieldrin was the most efficient material in 1950 in reducing larval populations (Table 2). This chemical formulation gave excellent results in both 1950 and 1951 and was one of the three most effective materials evaluated (Tables 2 and 3). This material did not affect the flavor of Elberta peaches treated three times (Table 7).

Parathion. This compound has been used as a wettable powder in 15 and 25 per cent strengths. In 1948 and 1949, 1 or 2 pounds of the 25 per cent formulation were used while in 1950 and 1951 a standard dosage of 2 pounds of the 15 per cent formulation in 100 gallons of water was used. In five cage tests parathion showed a high degree of toxicity to summer-brood adults. Affected beetles died soon after they showed initial symptoms of poisoning.

Parathion gave excellent control of plum curculio at the higher dosages in 1948 (Table 1). In the 1950 tests parathion did not possess enough residual activity to control beetles ovipositing late in the season. As a result, a considerable amount of fruit was injured and many larvae were reared from drop fruits after July 18 from parathion plots.

Residue investigations showed that about 0.09 parts per million of parathion results from a 3 or 4 application schedule to control curculio. Samples were taken 37 days after the final application. In other tests parathion was comparatively poor in residual action even at dosages of 2 pounds of the 25 per cent wettable powder in 100 gallons of water. Eighty-two per cent of the chemical disappeared in 5 days although measurable amounts persisted for at least 30 days.

Two varieties of peaches treated with from three to seven applications of parathion were judged to be normal in flavor by the taste panel (Tables 5, 6, 7).

DDT. DDT was tested only in preliminary tests and was quite ineffective against plum curculios in one cage test (Table 1). Processed Elberta peaches

treated with seven applications of DDT in 1949 tests did not show off-flavors.

Heptachlor. Heptachlor was very promising in preliminary screening tests (Table 2) but was not included in the 1950 field tests because of the limited number of trees in the experimental orchard. In 1951 this material was outstanding both in the control of larval populations and in protecting the fruit from curculio attack. Heptachlor knocked beetles down rapidly in cage tests (Tables 2 and 3) but the lethal action was slow. Fruit treated with heptachlor was judged to be normal by the taste panel (Table 7).

TEPP. Tetraethyl pyrophosphate gave quick knockdown where fresh deposits of the chemical were present on the foliage but its toxicity decreased rapidly within a few days. After 10 days TEPP killed but 20 per cent of the beetles which had fed upon treated foliage for 102 hours.

EPN. This material has been used at several concentrations but the most practical concentration appears to be 24 ounces of the 25 per cent wettable powder. EPN proved to be very toxic to beetles in cage tests and so was included in both the 1950 and 1951 field tests. This insecticide killed 100 per cent of the beetles in from 12 to 24 hours in 5 cage tests. In 1950 fields tests EPN was superior to parathion, aldrin, chlordane and benzene hexachloride. Although EPN was somewhat less effective than dieldrin and methoxychlor in reducing larval populations, it was more effective in protecting the crop from curculio "stings."

Residue studies indicated that about 0.5 parts per million of EPN resulted from a plum curculio schedule consisting of 3 applications. These investigations also showed that EPN was more resistant to weathering than parathion. Fruit samples from EPN plots which received three applications of spray were rated equal to untreated samples in flavor evaluations.

EON. EON showed considerable promise in preliminary screening tests (Table 2) but was not available for 1950 field tests. This material affected plum curculio very much the same as EPN in initial toxicity tests but appeared to have a little better residual action than EPN.

Compound 645A. This material was tested in 1949 cage tests at the rate of 1 and 2 pounds of a 50 per cent formulation. The toxicity of this material to adults was greater than benzene hexachloride, lindane and methoxychlor.

Compound 728. A 25 per cent formulation of this material was evaluated in a preliminary way in the 1950 cage tests (Table 3). Plum curculio mortalities of 30 per cent at the 4 pound rate and 35 per cent at the 8 pound rate were recorded for this insecticide after 132 hours exposure. These results would indicate that Compound 728 offers little in the way of control for the plum curculio.

Compound 645A+728. A mixture containing 8.33 per cent of 2-nitro-1,1-bis(p-chlorophenyl) propane and 16.67 per cent of 2-nitro-1,1-bis(p-chlorophenyl) butane, was cage tested in 1950 with fairly encouraging results (Table 3). At the 4 pound rate 100 per cent of the beetles were knocked down in 84 hours. Since this material gave a performance superior to several of the insecticides widely used as a commercial control, it appears that further work with this compound may yield some interesting information.

STM-1. STM-1 was tested in preliminary screening tests for both contact and residual action against plum curculio. This material killed only 10 per cent of the beetles in 132 hours by contact action and killed none by systemic action. Two pounds of a 40 per cent emulsifiable concentrate were diluted with 100 gallons of water in these experiments.

Compound 4049. A 50 per cent emulsifiable concentrate formulation of this material performed so well in 1950 cage tests that it was included in the 1951 field testing program. In cage tests the material compared favorably with the most effective materials. In cage tests the material was used at the rate of 2 and 4 pounds of a 50 per cent emulsifiable concentrate while in the orchard it was used at a concentration of 3 pounds of a 25 per cent wettable powder in 100 gallons. At this concentration a larval reduction of only 25 per cent was obtained. A relatively high percentage of drop fruits was also infested with larvae. In one series fruit samples from plots treated with this material were definitely off-flavor. One third of the judges rated these as low in the unacceptable category (Table 7).

STM-2. In 1951 cage tests this material killed only 15 per cent of summer brood curculios in 132 hours by contact

action but killed 100 per cent of the beetles by systemic action in 36 hours. In the systemic tests the basal end of peach shoots was immersed in a solution containing 2 pounds of a 32.1 per cent emulsion in 100 gallons of water. Care was taken to prevent any contact action and the accumulation of toxic vapors was eliminated by using an electric fan at low speed to ventilate the screened cages. In field tests this insecticide failed to give commercial control of curculio although a 57 per cent reduction of larvae was recorded. Elberta peaches sprayed 3 times with this systemic showed a residue of two parts per million 73 days after the final spray. Since the fruit was not harvested until September 4, the final residue would be somewhat less than the above figure. The treatments apparently did not impair the flavor of the fruit as shown in table 7.

Compound E838. This material was tested both as a systemic and as a contact poison. This compound killed 85 per cent of the beetles in 132 hours by contact action and 80 per cent in 132 hours by systemic action. This material appears to be unique in having both contact and systemic action.

Compound Q-137. Fairly encouraging results were obtained with this material in 1950 cage tests although it could not be included in the field program that year. Q-137 at the 1-pound rate killed 100 per cent of the beetles in 84 hours while at the 2-pound rate it required only 48 hours.

SUMMARY.—Cage tests indicate that ethyl p-nitrophenyl thionobenzene-phosphonate, ethyl 0-nitrophenyl thionobenzenephosphonate, dieldrin, heptachlor, parathion, chlordane (A) and S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (Compound 4049) possessed a high degree of toxicity to the plum curculio, *Conotrachelus nenuphar* (Hbst.). Aldrin and tetraethyl pyrophosphate also gave a high knockdown rate while only fair results were obtained with chlordane (B), 1,1-bis (p-ethyl phenyl) 2,2 dichloroethane (Compound Q-137), a mixture of 2-nitro-1,1-bis(p-chlorophenyl) propane and 2-nitro-1,1-bis (p-chlorophenyl) butane, diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin (Compound E838) and 2-nitro-1,1-bis (p-chlorophenyl) propane (Compound 645A). Technical benzene hexachloride, lindane, DDT, toxaphene, methoxychlor, acid lead arsenate, STM-1 (octamethyl pyrophosphoramide), STM-2 (a trialkyl thiophosphate), 2-nitro-1,1-bis(p-chlorophenyl) butane (Compound 728) and diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin (Compound E838) were of a low order of toxicity to adult insects.

Ethyl p-nitrophenyl thionobenzene-phosphonate and dieldrin gave excellent results in two years of field tests on Elberta peaches. In 1951 heptachlor gave a degree of field control equivalent to that of the two above chemicals. Methoxychlor was very effective in controlling plum curculio in 1950 but was rated fourth in over-all performance in 1951. Parathion gave good control in some field tests but only fair in others because of a lack of residual toxicity. Aldrin gave consistently good control in both 1950 and 1951 field tests. Chlordane gave variable results, the degree of control being determined by the formulation produced by different manufacturers. Benzene hexachloride was very effective in reducing larval populations but was ineffective against adults. STM-2 and S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (Compound 4049) gave only fair results in the field while acid lead arsenate and toxaphene even were comparatively ineffective.

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Ecological Studies on Overwintered Honey Bee Colonies

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The honey bee, *Apis mellifera* L., colony exists as a unit organism in which the individuals—queen, workers, and drones—serve as living cells of the whole. The individuals are subject to more or less constant replacement. The honey bee in its colony organization has the widest possible range of climatic adaptability of any insect species. It survives in nature from the warm tropics to the northernmost regions that permit a pollen- and nectar-producing flora adequate for its food supply. The honey bee is adaptable to seasonally extreme climatic conditions that may be either humid or arid, and temperatures may exceed 120° F. or 50° below zero.

Environmental factors important to the honey bee colony are those that influence the flora. Of course, weather conditions must be favorable for flower visitations by the bees during periods when pollen and nectar are yielded in copious quantity. The natural instinct of honey bees is to store large food reserves for use during dearth periods, whether they be from rain, drought, or extreme cold.

Throughout history man has utilized the productive capacity of honey bees. Sometimes his methods have been destructive, but in general he has treated the honey bee as his friend by anticipating its food requirements and providing some measure of shelter. The honey bees' instincts are inherently wild so bees are not subject to domestication. The success that man has attained in making honey bees more productive has been the result of making a close study of their normal behavior and then adapting practices in harmony with their habits to capitalize on their great industry. Man has made mistakes, but the tremendous reproductive capacity of honey bees has enabled the species to survive and increase.

The overwintering of honey bee colonies has been considered one of the most difficult problems of management. Winter losses, based on the number of colonies that do not survive, may average 15 per cent. The reduced productivity of colonies that do survive under poor wintering conditions may exceed by several times the apparent loss.

The Bureau of Entomology and Plant Quarantine, many state experiment stations, and European research laboratories have conducted numerous fundamental and applied experiments on wintering. An analysis of the work done strongly suggests that winter losses can largely be attributed to colony standards and methods rather than to climatic extremes. The control or recognition of only single variables in many experiments and observations on wintering explain the frequent contradictions in results or viewpoints.

Winter Hive Temperatures.—The function and need for hive insulation have been tested and debated for more than 100 years. Hive and cluster temperatures have been investigated by numerous research workers in the United States (Corkins & Gilbert 1930; Farrar

[1] In cooperation with the Wisconsin Agricultural Experiment Station.

Table 1.—Minimum hive temperature outside the cluster area.

Hive No.	Date	Interspace No.								
		1	2	3	4	5	—	7	8	9
4 (unprotected)	Jan. 29	10	7	9	10	14	—	12	19	12
	30	−1	2	−1	−3	−1	—	12	20	16
8 (packed)	29	10	12	12	18	14	—	14	14	13
	30	6	7	7	13	11	—	10	9	8
9 (packed)	29	− 3	−2	−2	−2	−2	—	−1	−1	−2
	30	−12	−13	(not recorded .....)						

1934, 1943, 1945, 1946, 1949; Gates 1914; Phillips & Demuth 1914; and Wilson & Milum 1927) and foreign countries (Armbruster 1924; Budel 1948, 1950; Hess 1926; and Himmer 1926, 1927). The conclusions drawn have been influenced by the instruments used, the class of colonies (strength and amount of hive equipment), the geographical climates, and, to a certain extent, the general concepts in bee management prevailing at the time the studies were made. However, an analysis of all the data published reveal few major points of conflict regarding temperature relationships.

The Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the Bureau of Entomology and Plant Quarantine and the University of Wisconsin, is currently conducting experiments on electrical heating of hives. Instruments for automatically recording temperatures from 1600 thermocouples in the experimental hives permit us to present here a limited amount of pertinent data from the unheated colonies used as checks in the hive-heating experiments.

The check colonies used included (1) unprotected hives, (2) hives wrapped with *sisalkraft* paper, and (3) hives packed with 2 inches of balsam wool. The packed hives were first wrapped with sisalkraft to provide a moisture barrier before applying the insulating balsam wool batts. These were then protected by an outside wrapping of sisalkraft paper. Eighty thermocouples were distributed in each of three shallow hive bodies containing frames 6.25 inches deep, or a total of 240 temperature points in each colony. Eight thermocouples were located in eight comb interspaces to form a transverse vertical grid with points located 1 inch apart from top to bottom of the three-story hive. In interspace 6 a horizontal grid of 16 points 1.12 inches apart was placed between the centers of combs 5 and 6 in each hive body.

Between January 28 and 31, 1951, the mean hourly temperature was −13.6° F. over a 65-hour period of subzero temperatures. On January 29 the mean hourly temperature was −15° (min. −19°, max. −9°), and on January 30 the mean was −16.75° (min. −36°, max. −2°). The extreme temperatures recorded within the hives about 8 A.M. along the lower edge of the bottom set of combs (outside air temperature January 29, −19°; January 30, −27°) are shown in table 1.

The temperatures (° F.) recorded on January 30 for interspace 7 (between combs 6 and 7, colony 4) and interspace 5 (between combs 4 and 5, colony 8) from top to bottom approximately through the center of the clusters are shown in the following tabulation:

Colony 4	Colony 8
Interspace 7	Interspace 5
Top Hive Body	
47	77
54	86
62	89
70	89
83	89
85	89
87	89
Center Hive Body	
90	92
91	92
91	92
92	92
92	90
91	87
89	83
Bottom Hive Body	
85	73
85	61
75	47
67	—
44	31[1]
—	21
24[1]	16
12	11

[1] Temperatures outside the cluster area.

The size and position of the cluster determine the temperature in any portion of the hive for a given outside temperature. The occurrence of subzero temperatures in both packed and unprotected hives shows that the bees do not attempt to heat the hive space unoccupied by the cluster. The lower temperatures recorded in packed hive No. 9 than in unprotected hive No. 4 are due partly to the position of the cluster in hive No. 9 and to the fact that snow extended around the bottom hive body of No. 4 but not around No. 9.

Under falling temperatures the packed hive cools off more slowly than does the unprotected hive and, conversely, under rising temperatures it warms up more slowly. Even with the restricted hive entrances, the exchange of air through a packed hive is large in proportion to the space unoccupied by the bees. For insulation to be effective, it would have to be placed around the cluster, rather than

Table 2.—Relationships between winter honey consumption and yields the following season.

CONSUMPTION BASED ON YIELDS				YIELDS BASED ON CONSUMPTION			
YIELD	NUMBER OF COLONIES	AVG. CONSUMPTION OCT. TO APRIL	AVG. YIELD OCT. TO OCT.	CONSUMPTION	NUMBER OF COLONIES	AVG. CONSUMPTION OCT. TO APRIL	AVG. YIELD OCT. TO OCT.
		Pounds	*Pounds*			*Pounds*	*Pounds*
			1947[1]				
Below avg.	22	45.5	103.5	Below avg.	23	43.0	159.1
Above avg.	29	54.8	241.1	Above avg.	28	57.4	208.5
Difference		9.3	137.6			14.4	49.4
			1949[1]				
Below avg.	27	63.8	94.3	Below avg.	29	56.7	147.5
Above avg.	30	68.7	197.8	Above avg.	28	76.3	150.0
Difference		4.9	103.5			19.6	2.5
			1949[2]				
Below avg.	81	49.4	55.6	Below avg.	83	45.1	85.5
Above avg.	82	50.8	113.1	Above avg.	80	56.3	83.5
Difference		1.4	57.5			11.2	−2.0
			1950[2]				
Below avg.	75	50.5	110.3	Below avg.	83	43.9	172.6
Above avg.	70	51.6	229.5	Above avg.	63	60.6	172.2
Difference		1.1	119.2			16.7	−0.4
Below avg.	205	51.3	85.8	Below avg.	217	46.0	134.5
Above avg.	211	54.2	181.4	Above avg.	199	60.6	138.5
Difference		2.9	95.6			14.6	4.0
Increased summer gain	211	—	98.5		199	—	18.6

[1] Colonies used in single- and two-queen management tests.
[2] Single-queen colonies used in testing stock lines.

around the hive, and in effect shut off all convection air currents between the warm air inside and the cold air outside.

The surface temperature of the cluster is between 43° and 46° F. As the air temperature around the cluster decreases, there is a concentration of bees in the outer area of the cluster, forming an insulating shell 1 to 3 inches deep, to retain the heat generated by the more active bees inside. The cluster temperature is regulated under falling temperature by contraction of the cluster and raising the temperature inside by increased activity of the center bees. A balance is maintained between the internal temperature, the diameter of the cluster, and the depth of the insulating shell, so that heat conducted from within will equal the small amount of heat radiated from the surface at approximately 45°. It is easy to understand why small populations have greater difficulty in maintaining this balance than full-strength colonies.

FOOD CONSUMPTION.—Starvation is the major cause of winter losses. It may result from inadequate stores or from their improper position and also from populations too small to maintain contact with their stores. Management practices prior to the winter period may influence all three situations. Maximum food requirements, rather than the average, must be satisfied.

A theory of conservation of bee energy and honey stores prevailed for many years. Hive insulation or cellar wintering was supposed to conserve bee energy and thereby conserve honey stores. It is sometimes possible to carry a small colony through the winter on less than 10 pounds of honey. Spring feeding was, of course, a recognized necessity. Minimum winter stores at different periods were stated to be 20, 30, 45, and 60 pounds of reserve honey. We now find it better to leave 90 pounds of honey, because the best colonies may use nearly that much, and it eliminates the necessity of spring feeding.

Thirty pounds more honey than the

average colony uses is cheap insurance, compared with the risk of losing the best colonies because they have even 1 pound too little. Colonies in an apiary showing average consumption of 55 pounds usually have a range of 30 to 80 pounds. An understanding of the importance of pollen in wintering has emphasized the need for larger honey reserves. Similarly, the utilization of more productive bee stocks has raised food standards.

The relation between winter consumption and colony yields is shown in table 2. The average winter consumption was calculated for 416 colonies, based on those yielding more and those yielding less than the average and on the average yields of those consuming more and those consuming less than the average.

The weighted means show that colonies yielding more than the average produced 95.6 pounds more surplus (from October to October), although they consumed 2.9 pounds more honey (from October to April), than those yielding less than the average. Their difference in gain during the active season would equal 95.6 plus 2.9, or 98.5 pounds. The weighted means show that colonies consuming more than the average produced 4 pounds more surplus while consuming 14.6 pounds more honey, and gained 18.6 pounds more honey during the active season than those consuming less than the average.

The actual weight differences are not important, because of variation in honey flows, productivity in stock, number and time of queen supersedures, occasional progressive robbing between colonies, and the time when weights are determined in the spring. It is significant that, on the average, high consumption results in greater net yields and a still greater advantage if productivity is measured in terms of pollination. Since pollination is directly proportional to the number of flower visits, the high summer gains become important.

The consumption values are influenced by the time when weights are taken in the spring. The above data were taken for the approximate period October 15 to April 15. In 1944 three unprotected colonies that were fed supplemented pollen cakes showed an average consumption of 22.9 pounds between October and May 25, which was 11.5 pounds less than three packed colonies that did not receive pollen supplement. This does not mean that the packed colonies consumed more honey during the winter. The unpacked colonies consumed more honey, but they made greater gains from an early honey flow in May because of their more advanced condition.

A summary of management standards favorable to good wintering under all climatic conditions may be enumerated as follows: (1) Unrestricted brood rearing to provide a normal population of 10 pounds of bees; (2) 45 pounds of honey in dark combs in the top hive body plus 20 to 30 pounds in each of two lower hive bodies; (3) 500 square inches of pollen reserves, or provision made to supply supplemented pollen cakes during March and April and such other period when pollen collection is below colony requirements; (4) freedom from Nosema infection or other disease; (5) provision of an auger-hole entrance in the upper hive body and a reduced bottom-board entrance; and (6) the location of hives in full sunlight and where they are protected from wind and provided with good drainage of air away from the hives.

The severity of climate and time of pollen and nectar resources influence to what extent one may deviate from the standards given. Snow coverage is not harmful. The upper auger entrances permit flight when the snow melts from above the hives, even should the bottom entrances become clogged. Small colonies or nuclei should either be united to normal colonies or wintered above these with a screen division board separating the upper and lower units. When wintered above, the nucleus should contain close to 45 pounds of honey in one hive body.

The honey bee colony is adaptable to a wide range of climatic conditions where these are favorable for pollen- and nectar-producing plants upon which the bees depend for food. The normal colony forms a cluster within its area of food stores. It produces and regulates its heat energy within well-defined temperature gradients (43° to 93° F.), independent of the air temperature surrounding the cluster. Insulation around the hive slows up the rate of temperature change, but in a cold climate it does not prevent subzero temperatures within the hive. Colonies that consume more than the average amount of stores produce the greatest yields.

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Residual Toxicity of Some Organic Insecticides to Japanese Beetles[1]

E. H. SIEGLER,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

During the summer of 1951 laboratory experiments were made at Beltsville, Maryland, to evaluate the toxicity of the residues of some of the new organic insecticides to the Japanese beetle, *Popillia japonica* Newm. The insecticides tested were parathion, EPN, DDT, methoxychlor, toxaphene, BHC, aldrin, and dieldrin. Two types of tests were made—(1) tests with sprays applied when the beetles were present, and (2) tests in which the beetles were exposed only to the aged residues. The first type of test simulated in a general way the spraying of infested plants, and the second type gave information on the toxicity of the residues as correlated with time. Similar experiments have been reported by Langford and co-workers (1951).

APPARATUS.—The test materials were applied with a compressed-air paint-type spray gun onto insect cages moving on a conveyer belt. Each cage consisted of one section of a petri dish 4 inches in diameter with a wire-screen top, the screen being soldered to a metal rim. In the bottom of each dish was placed a circular piece of filter paper 3.5 inches in diameter.

PROCEDURE.—Adult Japanese beetles were collected daily in the field for these tests. Therefore, their ages were not known, and the proportion of the sexes was not uniform.

In the tests with freshly applied sprays the cages containing the beetles were conveyed through the spray, and when the spray was dry the cage and filter paper provided for residual action during the period of the test.

In the tests with aged residues the open, empty cages were conveyed through the spray, and the beetles were confined in the cages several days later.

In both types of tests unsprayed slices of apple were enclosed in the cages to provide food for the beetles. Each material was applied to five replicate cages, and 20 beetles were placed in each cage. During the experimentation the cages were held under laboratory conditions.

The effectiveness of the treatments was measured by the percentages of dead and moribund beetles after various periods of time.

RESULTS AND DISCUSSION.—The results of comparing the effectiveness of

[1] Presented at the meeting of the Eastern Branch of the American Association of Economic Entomology, at New York City, November 15–16, 1951.

[2] The author acknowledges with appreciation with assistance given by Wallace C. Harding, Jr.

Table 1.—Effectiveness of fresh applications and aged residues of various insecticides against the adult Japanese beetle.

Insecticide Formulation	Pounds per 100 Gallons	Type of Test	Per Cent Dead or Morbidund After—		
			1 Day	2 Days	3 Days
Check (distilled water)	—	Fresh	1	9	16
		Residues aged—			
		7 days	0	8	11
		14 days	5	12	19
Parathion (25% W.P.)	0.2	Fresh	89	96	100
		Residues aged—			
		7 days	21	86	99
		14 days	7	42	69
DDT (25% W.P.)	1	Fresh	100	—	—
		Residues aged—			
		7 days	98	98	99
		14 days	100	—	—
Methoxychlor (50% W.P.)	0.5	Fresh	93	95	98
		Residues aged—			
		7 days	90	96	98
		14 days	86	95	97
Toxaphene (40% W.P.)	2	Fresh	100	—	—
		Residues aged—			
		7 days	54	94	100
		14 days	9	76	89
BHC (10% gamma, W.P.)	2	Fresh	100	—	—
		Residues aged—			
		7 days	95	100	—
		14 days	87	100	—
Aldrin (equivalent 25% W.P.)	1	Fresh	—	—	—
		Residues aged—			
		7 days	15	82	92
		14 days	6	47	63
Dieldrin (equivalent 25% W.P.)	1	Fresh			
		Residues aged—			
		7 days	100	—	—
		14 days	80	100	—

aged residues with fresh applications are summarized in tables 1, 2, and 3.

Parathion was the most effective material tested as a freshly applied spray. Residues 4, 7, and 14 days old (Tables 1 and 3) were not very effective during the first day of beetle exposure, but there was a noticeable increase in beetle mortality with time, probably as a result of cumulative toxic effects. Very little parathion was required to kill beetles present when the spray was applied. EPN at a comparable strength (Table 3) was less effective in both types of tests, but the mortality increased with continued exposure.

DDT, methoxychlor, aldrin, and dieldrin were tested at a concentration five times that of parathion. DDT and meth-

Table 2.—Effectiveness of fresh applications and 6-day-old residues of BHC and dieldrin against the adult Japanese beetle.

Insecticide Formulation	Pounds per 100 Gallons	Type of Test	Per Cent Dead or Moribund After—			
			1 Day	2 Days	3 Days	5 Days
Check (distilled water)	—	Fresh	1	7	—	17
		Aged	1	6	18	—
BHC (10% gamma, W.P.)	0.5	Fresh	100	—	—	—
		Aged	25	59	83	—
Dieldrin (equivalent 25% W.P.)	0.5	Fresh	100	—	—	—
		Aged	100	—	—	—
Dieldrin (equivalent 18.5% emulsifiable)	0.68	Fresh	100	—	—	—
		Aged	89	98	100	—

Table 3.—Effectiveness of fresh applications and 4-day-old residues of various insecticides against the adult Japanese beetle.

Insecticide Formulation	Pounds per 100 Gallons	Type of Test	Per Cent Dead or Moribund After—				
			1 Day	2 Days	3 Days	4 Days	5 Days
Check (distilled water)	—	Fresh	0	—	—	21	27
		Aged	0	18	24	—	—
Parathion (25% W.P.)	0.1	Fresh	89	—	—	100	—
		Aged	34	87	95	—	—
EPN (27% W.P.)	0.09	Fresh	59	—	—	95	97
		Aged	11	45	62	—	—
DDT (25% W.P.)	0.5	Fresh	89	—	—	100	—
		Aged	91	100	—	—	—
Aldrin (equivalent 25% W.P.	0.5	Fresh	100	—	—	—	—
		Aged	27	43	66	—	—
Dieldrin (equivalent 25% W.P.)	0.5	Fresh	100	—	—	—	—
		Aged	100	—	—	—	—
Aldrin (equivalent 23% emulsifiable)	0.54	Fresh	100	—	—	—	—
		Aged	41	79	89	—	—
Dieldrin (equivalent 18.5%	0.68	Fresh	100	—	—	—	—
		Aged	100	—	—	—	—

oxychlor were about equally effective whether the beetles were directly sprayed or exposed only to the aged residues (Table 1).

Aldrin and dieldrin were not tested as freshly applied sprays in the experiments reported in table 1, but in other tests (Table 2) these materials caused complete mortality of the beetles within 1 day. The residues of aldrin 4, 7, and 14 days old (Tables 1 and 3) gave results similar to those obtained with parathion. The aldrin residues were less effective than those of DDT, particularly the 14-day-old residue.

Dieldrin residues were highly effective. The 7- and 14-day-old residues killed all the beetles within 1 and 2 days, respectively (Table 1). Both wettable powders and emulsifiable concentrates of dieldrin were highly effective.

Toxaphene was more toxic than parathion at a concentration 16 times that of parathion. The toxaphene residues killed the beetles more slowly than did the DDT residues, when the concentration was 3.2 times as high as that of DDT. However, at the end of 3 days there was a marked cumulative toxic effect.

BHC was very effective both as a freshly applied spray and as 7- and 14-day residues. It was about as toxic as DDT.

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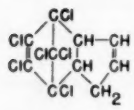
The Resolution and Chemical and Biological Characterization of Some Constituents of Technical Chlordane[1,2]

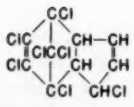
RALPH B. MARCH[3]

Kearns *et al.* (1945) first reported and discussed the physical characteristics and insecticidal activity of technical chlordane.[4] Although its chemical description was incomplete, they suggested that it was probably a mixture of various isomers. The presence of a number of possible constituents in the technical product can be proposed by inspection of the general reaction for the preparation of technical chlordane which follows:

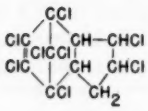
Depending upon the final degree of chlorination, the following constituents are possible:



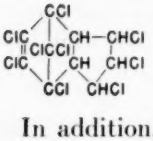
($C_{10}H_6Cl_4$) 4,5,6,7,8,8-hexachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene



($C_{10}H_5Cl_7$) 1 or 3a,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene

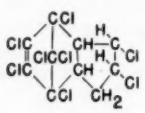


($C_{10}H_6Cl_8$) 2,3,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene

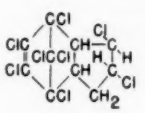


($C_{10}H_5Cl_9$) 3a or 1,2,3,4,5,6,7,8,8-enneachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene

In addition, the above analogues may exist in isomeric forms. The *cis-trans* isomer pairs of the octa- and enneachlor derivatives may be present; for example:

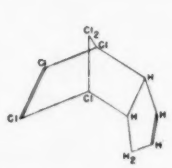


Cis-isomer of $C_{10}H_6Cl_8$

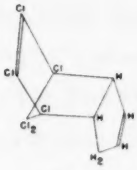


Trans-isomer of $C_{10}H_6Cl_8$

Based on the work of Bruson & Riener (1945), and Bartlett & Schneider (1946) who studied the isomeric relationships of certain compounds related to chlordane, it is also possible that *endo-exo* isomer pairs of the above derivatives could be present.



Endo-isomer of $C_{10}H_6Cl_6$



Exo-isomer of $C_{10}H_6Cl_6$

Attempts at separating these possible constituents by means of fractional distillation or differential solubility methods were unsuccessful. The comparatively recent and wide application of chromatographic adsorption analysis to the resolution of mixtures of organic compounds suggested that this method be investigated. Discussions of the principles of chromatography which relate to the work may be found in the literature (see Strain 1942 and Zechmeister & Cholnoky 1943).

EXPERIMENTAL.—*Chromatographic Adsorption Analysis. Apparatus and Materials.*—A simple adsorption column was constructed by reducing one end of a 19 by 500 mm. glass tube with another, 4 by 80 mm. The adsorbent was Merck anhydrous aluminum oxide (Al_2O_3) according to Brockmann. Sample K-190, May 27, 1946 of Velsicol 1068 Branch of technical chlordane was the principal solute. Both low boiling petroleum ether, b.p. 43–53° C. and medium boiling petroleum ether, b.p. 64–70° C. were used as solvents. Acetone was used for elution of the column. The separate fractions of the percolate were collected in a calibrated open-top separatory funnel and immediately transferred to numbered 20 by 70 mm. shell vials.

Adsorption Procedure.—The column was prepared for adsorption by addition of 300 mm. of adsorbent with vigorous agitation to insure uniform packing. A small cotton plug at the reduced end of

[1] Contribution from the laboratories of the Department of Entomology, University of Illinois.

[2] Presented at the annual meeting of the American Association of Economic Entomologists at Denver, Colorado, December 18–21, 1950.

[3] Present address: University of California Citrus Experiment Station, Riverside, California.

[4] Recorded February 27, 1947 by the Commission of Patents as the compound containing not less than 60% 2,3,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane and 40% related active compounds.

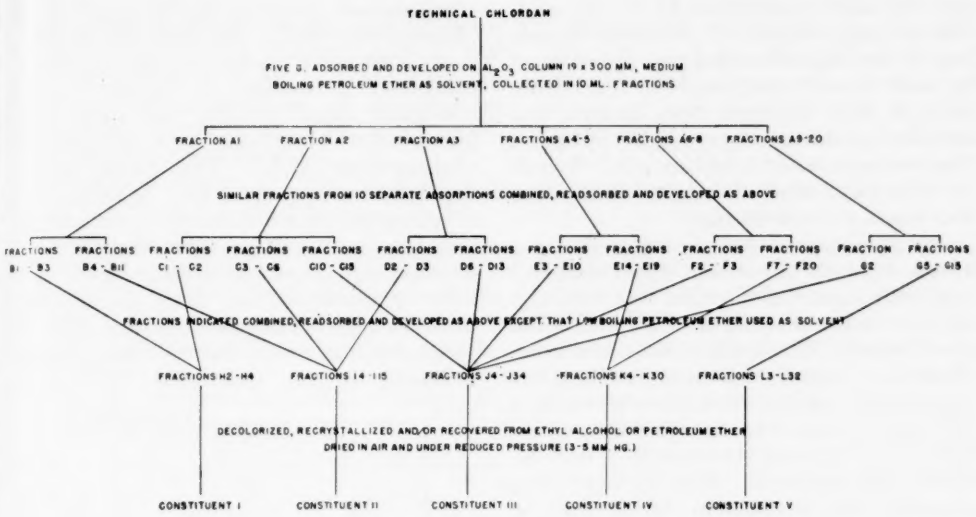

TECHNICAL CHLORDAN
FIVE G. ADSORBED AND DEVELOPED ON Al_2O_3 COLUMN 19 x 300 MM., MEDIUM BOILING PETROLEUM ETHER AS SOLVENT, COLLECTED IN 10 ML. FRACTIONS
FRACTION A1
FRACTION A2
FRACTION A3
FRACTIONS A4-5
FRACTIONS A6-8
FRACTIONS A9-20
SIMILAR FRACTIONS FROM 10 SEPARATE ADSORPTIONS COMBINED, READSORBED AND DEVELOPED AS ABOVE
FRACTIONS B1 - B3
FRACTIONS B4 - B11
FRACTIONS C1 - C2
FRACTIONS C3 - C6
FRACTIONS C10 - C15
FRACTIONS D2 - D3
FRACTIONS D6 - D13
FRACTIONS E3 - E10
FRACTIONS E14 - E19
FRACTIONS F2 - F3
FRACTIONS F7 - F20
FRACTION G2
FRACTIONS G5 - G15
FRACTIONS INDICATED COMBINED, READSORBED AND DEVELOPED AS ABOVE EXCEPT THAT LOW BOILING PETROLEUM ETHER USED AS SOLVENT
FRACTIONS H2 - H4
FRACTIONS I4 - I15
FRACTIONS J4 - J34
FRACTIONS K4 - K30
FRACTIONS L3 - L32
DECOLORIZED, RECRYSTALLIZED AND/OR RECOVERED FROM ETHYL ALCOHOL OR PETROLEUM ETHER
DRIED IN AIR AND UNDER REDUCED PRESSURE (3-5 MM. HG.)
CONSTITUENT I
CONSTITUENT II
CONSTITUENT III
CONSTITUENT IV
CONSTITUENT V

FIG. 1.—Flow diagram of chromatographic adsorption procedures.

the column was sufficient as a retainer. The remaining 200 mm. of the column were filled with solvent which was allowed to percolate into the column. Five g. of solute in 10 ml. of solvent were carefully added as soon as the above portion of solvent had nearly disappeared. When the 10 ml. portion containing the solute had in its turn almost entirely percolated into the column, additional solvent was added. During the subsequent development of the flowing chromatogram, the column was continuously refilled with solvent, thus maintaining a nearly uniform pressure and insuring an even flow of solvent at its own rate, 10 ml. per 2–3 min. Collection of the percolate was begun at the first indication of solute reaching the lower end of the column. The percolate was arbitrarily collected in 10 ml. fractions since it was not possible to follow the chromatogram by physical or chemical means. The column in its entirety was finally eluted with acetone. The solute fractions were obtained upon evaporation of the solvent.

Since it was found impossible to replenish the original Merck aluminum oxide, the used absorbent was reclaimed by heating to 400–500° C. for 8–12 hours. Considerable adsorption efficiency was lost with the use of this reclaimed material, though it was found to be more efficient than a substitute aluminum oxide or activated charcoal.

Five g. of solute were found to be about the maximum amount which could be adsorbed at one time within the limits of resolvability. The relatively large quantities of the constituents necessary for concurrent biological evaluation demanded that this amount be kept as large as possible and that "preparatory" techniques rather than "analytical" techniques be followed.

Low boiling petroleum ether was substituted for medium boiling petroleum ether in the final adsorptions in order to further slow the movement of the constituents along the column. In the case of medium boiling petroleum ether, the majority of the 5 g. of solute passed through the column in 200 ml. of solvent following the first appearance of solute in the percolate; low boiling petroleum ether, in 350 ml. of solvent. Initially the solute fractions were recovered from the percolate by evolution of the solvent with heat. Since this tended to increase discoloration, the solvent was later allowed to evaporate freely into the air.

Test Method.—Biological evaluations were accomplished against the large milkweed bug, *Oncopeltus fasciatus* (Dallas). The bugs were reared in sufficiently large numbers to meet requirements according to the method described by Worthley (1943). Test groups were prepared every third day by segregation and isolation of the newly molted adult females which were then conditioned for 10 days before use, thus providing a

uniform adult population 10–12 days old. The average weight of an adult female bug at the time of testing was determined by individually weighing 100 bugs from each of five different test groups and calculating the average weight by mass. The average weight for an adult female 10 to 12 days after molting to adult state was found to be 80.8 mg.

A calculated dose of toxicant in a measured drop of solvent, approximately 1.00 ± 0.05 mm.^{3} of dioxane, was topically applied to the scutellum of an individual adult female. This application was accomplished by means of a number 26 gauge hypodermic needle bent downward at a 90° angle from the horizontal, ground flat at the tip and attached to a 0.25 cc. tuberculin syringe. The syringe was mounted on a wooden block and so arranged, in a manner similar to that described by Trevan (1922) and Kearns *et al.* (1945), that the plunger could be driven forward by a hand-driven micrometer caliper, calibrated in 10^{-3} in. The desired concentration of toxicant in mg./ml. was prepared by diluting a known amount of toxicant, weighed to the nearest 0.1 mg. in dioxane, measured to the nearest 0.01 ml. For the syringe used throughout this investigation, the average delivery was determined to be 1.01 mm.^{3} per 5×10^{-3} in.

Test lots of 100 bugs each were used for the determination of time-mortality data at various dosages. The bugs were individually treated as previously described, and then held for observation in pint jars provided with food and water. Twenty insects were confined in a jar for convenience of observation and to avoid overcrowing. Mortalities (the criterion for death was considered to be the incapability of movement other than tremors) were determined at 24 ± 1 hour intervals over a 144-hour period following treatment.

RESULTS —*Chromatographic Adsorption Analysis* —A series of adsorptions, combinations of solute fractions and readsorptions as shown in the flow diagram (Fig. 1) were necessary in order to achieve resolution of the constituents. Ten adsorptions, each of 5 g. of technical chlordane (Adsorption A), were initially accomplished. Physically and biologically similar solute fractions from these 10 adsorptions were combined and these combinations were separately readsorbed (Adsorptions B-G). Selected solute fractions from these readsorptions were again combined according to physical and biological characteristics and the combined solute fractions were readsorbed (Adsorptions H-L). The mean solute fractions from each of this second series of readsorptions were separately combined and the combinations were then further purified by decolorization, recrystallization or filtration and dried in air and under reduced pressure (3–5 mm. Hg) to yield the final constituents. Since it was necessary to use "fractional" adsorption

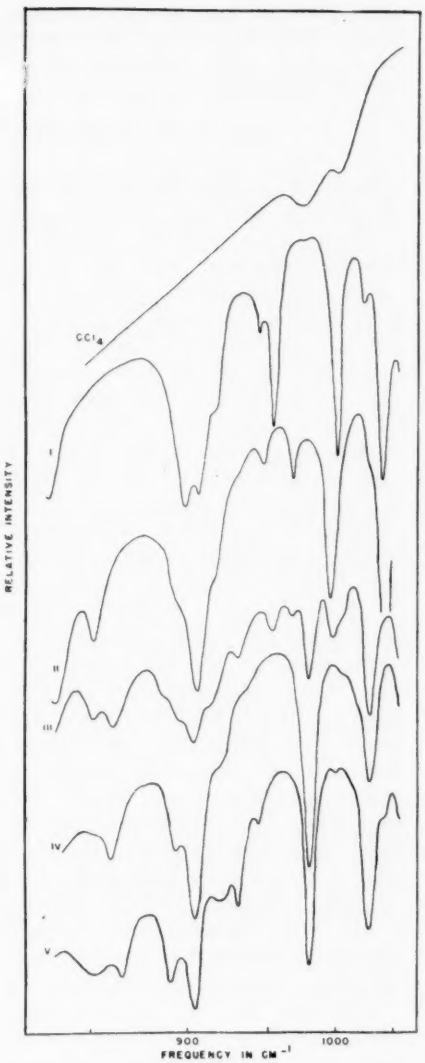


FIG. 2.—Tracings of infrared spectra for chlordane constituents and CCl_4.

procedures of successive adsorptions, combinations of similar solutes and readsorptions in order to achieve resolution, the determination of quantitative data was impractical. Thus, only qualitative data are presented.

Chemical Analyses.—The following data are presented for constituents I to V:[5]

Constituent I. White crystalline solid, m.p. 154° C. —decomposes.
Analysis. Calculated for $C_{10}H_6Cl_6$: C, 35.44; H, 1.79; Cl, 62.77.
Found: C, 35.10; H, 1.88; Cl, 62.99.
Constituent II. White crystalline solid, m.p. 92°–93° C.
Analysis. Calculated for $C_{10}H_5Cl_7$: C, 32.17; H, 1.35; Cl, 66.48.
Found: C, 32.36; H, 1.70; Cl, 66.22.
Constituent III. Colorless to faintly yellow viscous liquid, N 20/d 1.5804.
Analysis. Found: C, 31.53; H, 1.76; Cl, 66.26.
Constituent IV. White crystalline solid, m.p. 104.5°–106° C.
Analysis. Calculated for $C_{10}H_6Cl_8$: C, 29.31; H, 1.48; Cl, 69.21.
Found: C, 29.39; H, 1.75; Cl, 69.16.
Constituent V. White crystalline solid, m.p. 106.5°–108° C.
Analysis. Calculated for $C_{10}H_6Cl_8$: C, 29.31; H, 1.48; Cl, 69.21.
Found: C, 29.37; H, 1.62; Cl, 69.14.

Infrared Analyses.—The infrared analyses were accomplished in a 0.05 mm. thick rock salt cell on a Perkin-Elmer Infrared Spectrophotometer, Model 12b.[6] All of the constituents were examined in CCl_4 solution of arbitrary concentration. The absorbtion spectra from 4000 to 650 cm.$^{-1}$ were determined. Illustrative sections of the spectra from 1050 to 850 cm.$^{-1}$ (tracings of the records obtained from the instrument) are presented in figure 2.

Biological Evaluation.—Critical dosage mortality curves for 96 hours following treatment were determined according to Bliss (1933) and Finney (1947) for technical chlordane and constituents II, III, IV and V (Fig. 3). Constituent I required such high dosages that it was impractical to complete comparable data because of the high concentrations necessary. The LD_{50} values for the adult female large milkweed bug for 96 hours following treatment are as follows: technical chlordane, 143 ± 2 microg./g. ave. bug wgt.; constituent I, >1000 (4 per cent mortality at 75 microg./bug); constituent II, 31 ± 1; constituent III, 232 ± 7; constituent IV, 459 ± 14; and constituent V, 47 ± 1.

DISCUSSION.—According to the chemical analyses of the isolated constituents, constituent I corresponds to the compound of empirical formula $C_{10}H_6Cl_6$; constituent II, $C_{10}H_5Cl_7$; and constituents IV and V, $C_{10}H_6Cl_8$. The chemical analysis of constituent III does not conform to any set of the theoretical values within the limits of experimental error. The chemical analyses do not indicate the presence of higher chlorinated derivatives among the components isolated. It is possible that with the particular sample of chlordane used which contained a considerable quantity of constituent I, that chlorination had not proceeded to a high enough level to produce separable amounts of higher chlorinated derivatives.

Comparison of the infrared absorption spectra shows that constituents I, II, IV and V are distinctly different compounds. The spectrum of constituent III contains all the strong bands present in the spectrum of constituent IV plus many additional bands. These additional bands do not appear to be due to the presence of constituents I or II. This indicates that constituent III may be a mixture of constituent IV and one or more other components. Figure 2 illustrates the above points.

The biological data indicate that all of the constituents are distinct in their degrees of insecticidal activity. The approach of the toxicity of constituent V to that of constituent II serves additionally to separate if from constituent IV. The toxicity data for constituent III indicates that it may be a mixture of constituents II and IV, though the infrared spectra do not bear this out.

From the obove evidence, it is postulated that constituent I is 4,5,6,7,8,8-hexachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene; constituent II is 1 or 3a, 4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetra-hydro-4,7-methanoindene; and constituents IV and V are the *cis-trans* isomer pair of 2,3,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene. It is further postulated that constituent IV is the *cis* isomer and constituent V is the *trans* isomer. This postulation is based largely on the fact that constituent V is

[5] Chemical analyses by Clark Microanalytical Laboratories, Urbana, Illinois.
[6] Infrared analyses by Mrs. J. L. Johnson, Department of Chemistry, University of Illinois, Urbana, Illinois.

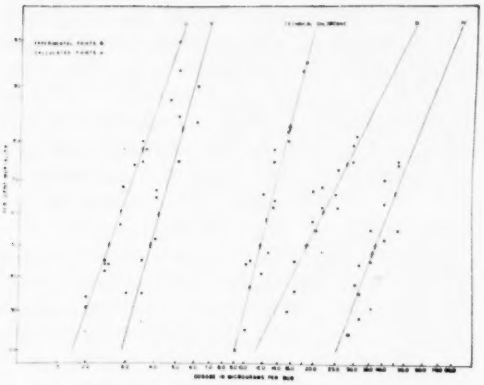


FIG. 3.—Dosage-mortality curves for 96 hours following treatment for technical chlordane and constituents II, III, IV, and V.

stable to dehydrochlorination by alcoholic KOH, whereas constituent IV is readily dehydrochlorinated by this reagent. The separate identity of constituents IV and V is also supported by the fact that their mixed melting point is 88° C. According to the constituents isolated, it does not appear that *endo-exo* isomer pairs are present, nor is there any indication of which of the pair is present. Higher chlorinated derivatives were not isolated among the major constituents though further work remains to be done on this possibility.

An interesting sidelight to this investigation is the fact that compounds identical with constituents II, IV and V[7] have been commercially synthesized in pure form. Their identity has been established by means of separate and mixed melting points, chemical analyses and biological evaluation.

SUMMARY.—1. By means of chromatographic adsorption techniques, technical chlordane was separated into four physically, chemically and biologically distinct crystalline constituents and an unknown liquid mixture.

2. The four distinct constituents are postulated to be: 4,5,6,7,8,8-hexachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene; 1 or 3a,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene; *cis*-2,3,4,-5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene; and *trans*-2,3,4,-5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene.

3. It appears that only one isomer of the *endo-exo* isomer pair is present. The identity of that isomer was not determined. Higher chlorinated derivatives were not found to be present in the sample of technical chlordane concerned.

4. LD_{50} values in microg./g. of ave. bug wgt. were determined for the adult female large milkweed bug for 96 hours following treatment.

[7] Samples of "Heptachlor," Alpha-chlordane and Beta-chlordane, respectively, furnished by Julius Hyman and Co., Denver, Colorado.

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Reduction in White-Fringed Beetle Injury by DDT Treatments[1]

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Studies were initiated in 1947 to determine the environmental conditions most conducive to economic damage by *Graphognathus peregrinus* Buch., one of several white-fringed beetle species known to injure crops in the southeastern part of the United States. These studies included observations on larval populations and crop damage in a farming area near Collins, Miss., before and after treatment of the soil with DDT, and comparative-stand counts of pasture plants and weeds growing in DDT-treated and untreated portions of land near Wiggins, Miss.

Larval-population and crop-damage surveys were made in 1947, and control measures were applied late in the winter of 1947–48 by the Bureau of Entomology and Plant Quarantine in cooperation with the Mississippi State Plant Board. It was thus possible to study the effectiveness of control measures with DDT for reducing larval populations to levels below those causing economic damage to crops.

Previous studies conducted in southern Mississippi indicated that serious injury to crops by the larvae of this white-fringed beetle usually occurred on land that was plowed and planted for the first time after remaining idle for several years. Since past utilization of the land might therefore be an important factor affecting the potential destructiveness of this insect, the crop-damage studies were conducted in fields having different histories of cultivation prior to the planting season of 1947.

Studies were also made to compare the effect of different larval populations on specific pasture plants and weeds growing in treated and untreated areas. Since DDT soil and foliage treatments greatly reduce subsequent larval populations without causing injury to most plants, a comparison of plant and larval densities in treated and untreated areas should indicate the over-all destructiveness of white-fringed beetle larvae, at least in environments where other soil-inhabiting insects are of no great importance.

Crop Damage and Larval Populations in Study Area before Treatment.—

A survey was made in the spring of 1947 to find a suitable area in which to conduct these studies. All reports of crop damage by white-fringed beetle larvae were carefully checked, and inspections were made on farm land wherever economic populations of *Graphogntahus peregrinus* were known to exist. Damage was reported in many farming communities, and it soon became apparent that detailed studies could not be made on each farm known to be damaged or to have high populations of white-fringed beetle larvae. An effort was therefore made to locate a single area having a number of infested farms showing economic damage. The Williamsburg community near Collins, Miss., was selected, since it encompassed the greatest number of farms showing damage, and therefore valid comparisons could be made because of similar farming practices.

Nine fields of cotton and seven fields of corn, comprising a total of 258 acres, were selected for study. A map of each field showing terraces, ditches, woods, and crop acreages was made to scale. Five or ten study sites in each field were then selected at random so as to give a uniform coverage of the entire field without reference to the extent of damage visible at the time of starting the tests. At each site a 50-foot section of planted row was marked with permanent stakes, but the cooperating farmers were requested to disregard these stakes and continue normal cultivation in the entire field.

For estimates of the damage to a particular crop grown in a given environment, the roots of each dead, dying, or injured plant were examined for feeding injury by white-fringed beetle larvae. When injured plants were found, a search was made for the insect believed to be responsible. Any white-fringed beetle larvae found near the injured roots were noted and then placed back into the soil so as to

[1] Presented at the meeting of the American Association of Economic Entomologists in New York, N. Y., Dec. 13–16, 1948.

[2] The writers acknowledge the assistance of Irving Keiser in supplying the plant-density data for the DDT-fertilizer test plots, and of R. E. Warner, W. Breland, J. M. Allen, and J. D. Tynes in collecting the field data. The treatments were applied under the supervision of S. S. Sheffield.

Table 1.—Injury to cotton and corn by white-fringed beetle larvae before and after treatment. Observations May-June 1947 and 1948. Treated February-March 1948.

Test Field	Before Treatment (1947)				After Treatment (1948)			
	Highest Per Cent of Plants Injured or Dead		Per Cent of Normal Stand		Highest Per Cent of Plants Injured or Dead		Per Cent of Normal Stand	
	Cotton	Corn	Cotton	Corn	Cotton	Corn	Cotton	Corn
J. Hall #1	21	—	51	—	—	0.4	—	112
J. Hall #2	29	—	38	—	—	0	—	114
S. Pierce	29	45	44	18	—	.4	—	112
P. Lott	23	—	36	—	0	—	111	—
F. Cameron	4	11	71	68	0	—	88	—
E. Campbell	12	—	39	—	0	—	111	—
V. Campbell	—	20	—	49	0	—	[1]	—
A. Wright	9	—	70	—	—	0	—	65
R. Mooney	30	8	26	67	0	0	77	72
T. Yates	—	18	—	60	0	0	97	83
W. Spencer	—	20	—	73	0	0	82	111
S. Legett #1	49	—	[2]	—	0	0	61	101
S. Legett #2	—	33	—	61	—	0	—	101
Mean	23	22	47	57	0	0.1	90	97

[1] No stand counts made.
[2] Field abandoned before stand counts were made because of excessive larval injury.

disturb the population as little as possible while the studies were in progress. Examinations were continued until no further larval damage was found, or until the crop was either plowed and replanted or abandoned. As many injured plants disappeared between inspection dates, the mean highest percentage of injured or dead plants was used as the estimate of damage for comparative purposes.

To determine the correlation between larval population and plant injury the larvae were counted in soil samples taken at two points on a 50-foot section of planted row adjacent to the one under study. At each point six 4-inch cores of soil were taken to a depth of 6 inches, or 12 cores in a 50-foot section of planted row.

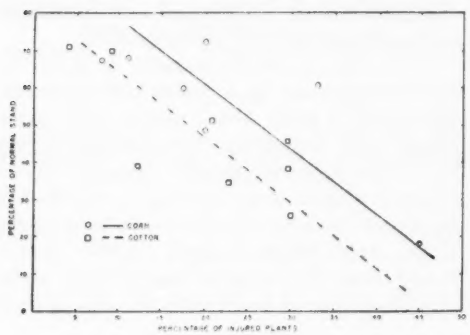

FIG. 1.—Comparison between plant injury and percentage of normal stand of cotton and corn on 13 study farms infested with white-fringed beetles. Williamsburg community, Collins, Miss., 1947.

In addition to the observations on injured and dead plants in a particular study site, the amount of damage was determined by comparing the number of surviving cotton or corn plants with the normal stand of identical crops in nearby non-infested, undamaged fields. These normal stands were determined by counting the living plants in ten 50-foot sections of row in each of eight uninfested fields also planted to these same crops, and were found to be 60 cotton and 19 corn plants per 50-foot section. Although this procedure does not reveal the exact amount of damage in any particular field, because of differences in planting dates, sources of seed, soil fertility, cultivation and thinning practices, and soil types, it should furnish a reasonably accurate over-all estimate of the damage attributable to white-fringed beetle larvae. The percentages of injured or dead plants and of normal stand of cotton and corn in the different fields are shown in table 1.

The mean highest percentage of plants found on any one inspection date to be injured by white-fringed beetle larve was 23 for cotton and 22 for corn. When the stands in these damaged fields were compared with the normal community stands, there was an average loss of 53 per cent of cotton and 43 per cent of corn plants.

Table 2.—Effectiveness of DDT soil treatments in reducing populations of white-fringed beetle larvae of the same generation against which the insecticide was applied. Fields treated February-March 1948.

Test Field	Acres Treated	Larvae per Sq. Yd.			Per Cent Reduction to May–June 1948	
		May–June 1947	February 1948	May–June 1948	From February 1948	From May–June 1947
Treated Fields						
S. Legett 1	16	138	237	3	99	98
S. Legett 2	4	88	165	3	98	97
T. Yates	8	92	206	2	99	98
J. Hall 1	2	66	146	2	99	97
J. Hall 2	15	114	83	3	96	97
S. Pierce	58	114	155	16	90	86
P. Lott	35	65	203	3	99	95
E. Campbell	14	63	143	3	98	95
F. Cameron	18	64	91	1	99	98
A. Wright	14	41	124	1	99	98
R. Mooney	28	48	76	2	97	96
W. Spencer	30	66	158	14	91	79
V. Campbell	16	34	72	2	97	94
Mean	—	76	143	4	97	94
Untreated Fields						
P. Lott	—	20	307	112	64	+460
S. Pierce[1]	—	65	155	154	1	+137
J. Jordan	—	158	—	244	—	+54
T. Campbell	—	86	227	83	63	4
Mean	—	82	230	148	43	+162

[1] Portion of same field listed under treated fields.

Actually a much greater loss was sustained, since the reduction in yield of living but stunted plants was not considered. That most of these losses could be attributed to white-fringed beetle larvae is indicated by the excellent negative correlations between the mean highest percentage of cotton and corn plants found to be injured and the percentage of normal stand of these two crops in the infested fields under study. Comparison of these factors showed correlation coefficients of −0.81 for cotton and −0.78 for corn. It is significant that the regression curves for the two crops are almost identical, although at different levels (Fig. 1).

As would be expected, there was a positive correlation between plant stand and crop yield. According to one farmer in the infested area, only 3 bales of cotton were grown during 1947 in a 17-acre field that normally produced 12 to 14 bales and has yielded as many as 17. Other growers indicated losses of 50 to 70 per cent.

In all the study sites there was an average of 76 larvae per square yard in 1947 (Table 2). The counts were made from May 28 to June 4, after much of the damage had been done and when heavy reductions attributable to natural causes already had been sustained. Although such counts are therefore not adequate for showing close correlations between larval density and crop damage within individual fields, they are indicative of the over-all population levels in the combined fields at that particular time and may be used for comparing such populations with those in the same fields on comparable future sampling dates.

CONTROL OPERATIONS IN 1948.—DDT was applied to the soil of most of the heavily infested farms in the Williamsburg community from February 18 to March 25, 1948. These applications were made as suspensions at the rate of 10 pounds of DDT in 12 gallons of spray liquid per acre, with a tractor-mounted concentrated-spray machine developed by the Bureau for use in white-fringed beetle control. All fields were disked as soon as possible after the treatment, usually within 24 hours, in order to incorporate the DDT into the soil before it

would deteriorate through weathering (Fig. 2). Approximately 500 acres were treated in this manner, 258 of which were on the farms under observation for crop damage in 1947.

EFFECT OF SOIL TREATMENT ON LARVAL POPULATIONS.—To evaluate the effectiveness of DDT soil treatments on larval populations of the same generation, counts were made in May and June 1947, in February 1948 just before the fields were treated, and again in May and June of that year. Since larval mortality is naturally high in the spring, counts were also made for comparison in several untreated fields.

The results of these tests are summarized in table 2. The reduction in larvae from February to May-June 1948 was 90 to 99 per cent in the treated fields, which was much higher than the natural mortality in the untreated fields. From May-June 1947 to an identical period in 1948 reductions were nearly as high (79 to 98 per cent) in the treated fields, whereas populations increased greatly in the untreated fields. In seven other untreated fields nearby, which were sampled for the first time between May 27 and June 2, 1948, the larval populations averaged 94 per square yard. It is thus apparent that the population levels in the treated fields were very low compared with those in the untreated fields in the area. Evidently it was the soil treatments in February-March 1948, rather than natural causes, that reduced larval populations to such extremely low levels in the following 3-month period.

Larval size was determined by washing infested soil through a series of sieves. When the soil treatments were begun, 56 per cent of the larvae were small (caught on a 24-mesh screen) and 41 per cent were medium in size (caught on a 16-mesh screen). Since DDT soil applications are effective against small and medium-size larvae, it is apparent that the treatments were made at a favorable time in the life cycle of the insect.

EFFECT OF SOIL TREATMENT ON CROP DAMAGE DUE TO BEETLE LARVAE.—To study the effectiveness of the DDT soil treatments in reducing the amount of crop damage in the spring of 1948, plant-injury counts were made between May 5 and June 14. The same sampling methods were employed as in 1947, and the damage counts for both years are therefore directly comparable (Table 1). No damage to cotton was noted, and only a negligible number of the corn plants were injured.

Since no community-stand counts were made in 1948, the stands of cotton and corn in the treated fields for that year were compared with the normal stands of the previous year. Table 1 shows that the treatment reduced damage to these crops from approximately a 50 per cent level in the year preceding treatment, to a negligible one during the season that treatment was applied. These results indicated that a single application of DDT at the rate of 10 pounds of insecticide per acre and immediately disked into the soil will reduce larval populations to levels below those causing economic damage to crops. It is possible that such treatment will remain effective for a number of years.

EFFECT OF PAST LAND USE ON LARVAL POPULATIONS AND CROP DAMAGE.—There had been some indication that larvae of *Graphognathus peregrinus* caused serious injury to crops on land plowed and planted for the first time after remaining idle for a number of years. Therefore, plant-injury and larval-population data from 15 infested cotton fields, including the nine regular study fields, were grouped according to past land utilization for analysis.

The greatest plant injury (32 per cent) found on any single inspection date and the highest larval population (101 per square yard) were in the fields that had been idle for 1 year, followed by those that had remained idle for 5 years. The least plant injury (24 per cent) and the lowest larval population (58 per square yard) were found in the fields that had been in continuous cultivation for 5 years.

EFFECTIVENESS OF DDT TREATMENTS IN REDUCING DAMAGE TO PASTURE PLANTS AND WEEDS.—In contrast with certain other white-fringed beetle species, particularly *Graphognathus leucoloma fecundus*, *G. peregrinus* was able to maintain relatively high larval populations on land that had been idle for a number of years, or in pastures that had received only an occasional disking. In such environments are certain pasture plants and weeds that may be killed by white-fringed beetle larvae if conditions are favorable for the

development of high populations of this insect. Additional observations were therefore made on the effectiveness of DDT treatments in reducing injury to native vegetation by white-fringed beetle larvae.

In August 1947 DDT was applied, alone and in combination with certain fertilizers, as a suspension spray at the rate of 25 pounds of insecticide per acre, to seventeen 15- by 15-foot plots in a pasture at Wiggins, Miss. Each plot was surrounded by an untreated area 15 feet wide. The entire field was disked both before and after treatment to incorporate the insecticide into the soil and to make all cultivation practices identical in the treated and untreated areas. In the spring of 1948 *Lespedeza* and *Euthamia* came up in these plots, and in June there were 89 per cent fewer *Lespedeza* and 82 per cent fewer *Euthamia* plants in the untreated than in the treated areas. These reductions must be attributed to the white-fringed beetle larvae (15 per square yard in the treated areas, as compared with 298 in the checks), since this was the only soil-inhabiting insect found in appreciable numbers. In October 1948 the grass and weeds in the test area were mowed to expose the *Lespedeza* plants. The abundance of green plants on the treated plots in contrast to the sparse vegetative cover in the surrounding untreated areas gave a checkerboard effect.

In May 1946 a single surface application of 5 or 10 pounds of DDT per acre in 6 gallons of spray (emulsion or suspension) was made to 16 three-fourth-acre plots in a pecan grove that had not been cultivated for 3 years and therefore contained many weeds. These treatments were ineffective against first-generation larvae, and populations were high in all the plots in the spring of 1947. During the adult-emergence season of that year, the weed foliage on half the plots received five applications at the rate of 1 pound of DDT per acre in 6 gallons of spray emulsion. These treatments gave high adult mortalities followed by extremely low populations of first-generation larvae. In August 1948 there were 50 per cent fewer *Lechea* plants in the check plots than in the plots receiving the surface applications of DDT in 1946, and 77 per cent fewer than in the plots receiving this treatment and also the five foliage applications in 1947. These reductions in plant stands were associated with larval-population counts made in January-February 1948 of 215 larvae per square yard in the checks, as compared with 86 in the plots treated in 1946 and 10 in those treated in 1946 and 1947.

On May 10, 1946, DDT was applied as a soil treatment to 50- by 50-foot plots of idle land near Wiggins, Miss., at the rate of 5 or 10 pounds per acre in 60 gallons of emulsion or suspension, and the entire field was disked soon after treatment. During the spring of 1947 there was a sparse stand of toadflax, *Linaria canadensis* L., over the entire field, although the plants were much more abundant on the plots receiving soil treatments in 1946 than in the checks or in the untreated areas 20 to 30 feet wide surrounding each treated plot.

Soil samplings made in February 1947 indicated average populations of 107 larvae per square yard in the treated plots and 1030 in the checks.

SUMMARY.—The white-fringed beetle, *Graphognathus peregrinus* Buch., was found to cause serious damage to stands of cotton and corn at Collins, Miss., in 1947. Feeding by larvae of this species caused apparent losses of approximately 53 per cent in cotton and 43 per cent in corn. Actually, much greater losses were sustained, because reductions in yield of stunted plants were not considered. The greatest losses and highest larval populations were on land that had been idle for only 1 year, and the next greatest on land that had remained idle for 5 years or more. The least damage and the lowest larval populations were on land that had been in continuous cultivation for at least 5 years, but economic damage on this land was also serious.

Soil applications of DDT during the winter of 1947–48 reduced larval populations to such extremely low levels that almost no larval damage was found in cotton or corn the following summer.

Larvae of this beetle also reduced stands of pasture plants and weeds when environmental conditions were favorable to the development of high populations. Such damage was materially lessened with the application of DDT.

Control of Pests Attacking Apples, Peaches, and Pears with Nitroparaffin Compounds

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The introduction of DDT in 1943 and its general adoption for the control of the codling moth, *Carpocapsa pomonella* (L.), and the oriental fruit moth, *Grapholitha molesta* (Busck), contributed greatly to the control of these major pests of fruit. However, since the action of DDT is limited to certain insects, other insecticides, such as lead arsenate, TDE, and parathion, must be included in the spray schedule to assure control of all injurious insects that may be present. Although good control of all fruit pests has been obtained with combinations of these insecticides, any one of them used alone has certain limitations. Some are effective against only one or two pests and others weather so rapidly that they remain effective for a short time only.

Studies of insecticides that would control many of the common pests of apple and peach and maintain protective residues over a long period have included extensive testing of two nitroparaffin compounds, CS-645A[1] and CS-674A.[2] A mixture of these compounds, known as CS-708[3] has also been tested.

These nitroparaffins were tested by the senior author in 1949 in cooperative experiments with the New York Agricultural Experiment Station at Poughkeepsie. In 1950 and 1951, at Vincennes, Ind., the mixture was used in all tests. It contained, by weight, 53.3 per cent of CS-674A, 26.7 per cent of CS-645A, and 20 per cent of related compounds.

The results of tests with these materials are presented in this paper, even though further research on their effectiveness and toxicity to higher animals is needed and the present cost of manufacture is such that their general use cannot be recommended. In the tables the abbreviation "WP" refers to a wettable powder, and "EM" to an emulsifiable formulation.

Spray residues of the mixture were determined by the colorimetric method of Jones *et al.* (1951).

Apple Pests.—CS-708 was tested against insects attacking apples in single-tree field plots, replicated four to six times in comparison with DDT and parathion. The formulations tested included a 25-per cent emulsion in a pine-oil base, 18-per cent and 50-per cent wettable powders, and a 25-per cent wettable powder impregnated on tobacco stems by a commercial process. The 18-per cent wettable powder was supposedly a 50-per cent material, but after it had been used in the calyx and four cover sprays it was found to contain only 18 per cent of CS-708. In the fifth to seventh cover sprays a 50-per cent CS-708 wettable powder was substituted for it. Treatments and results are shown in table 1.

At the strengths at which the materials were tested CS-708 compared favorably with DDT and was superior to parathion in controlling the codling moth. It controlled the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), and the plum curculio, *Conotrachelus nenuphar* (Hbst.), better than DDT and as well as parathion.

Additional information on the value of CS-708 for codling moth control was obtained in 1951. Field-sprayed Winesap apples, 60 per test, were removed from each plot and infested in the laboratory on July 17, 12 days after the fifth or just before the sixth cover spray, and again on July 17, immediately after the sixth cover spray, and on July 30, 13 days after the sixth cover spray. Each apple was infested with 10 newly hatched codling moth larvae and observed at various intervals thereafter. Treatments compared and the results effected by them are given in table 2. Four pounds of 25-per cent CS-708 wettable powder per 100 gallons proved superior to 2 pounds and compared favorably with standard quantities of DDT and parathion. Lead arsenate was markedly inferior to CS-708.

Two types of laboratory tests against larvae of the red-banded leaf roller in 1951 indicated further that CS-708 may control that insect. In one type the spray was applied to infested leaves and in the other sprayed leaves were infested with the insects. The results, given in table 3, show that 4 pounds of a 25-per

[1] *Prolan.* [2] *Bulan.* [3] *Dilan.*

Table 1.—Control of apple insects, Vincennes, Ind., 1950–51. Field Tests.

Insecticide (Quantities per 100 Gal.)	Average Number of Apples per Tree	Per Cent of Fruit Injured by—				Residue (p.p.m.) on Fruit at Harvest
		Codling Moth		Red-Banded Leaf Roller	Plum Curculio	
		Wormy	Stung			
1950: Reed Orchard; Variety, Gallia Beauty; 7 cover sprays (May 18, 29, June 8, 19, July 10, 28, and Aug. 10)						*Sept. 26*
CS-708, 25% Em 2 qt.	3888	0.1	0.6	0.1	0.6	1.2
DDT 50% WP 2 lb.	3234	0.3	0.2	3.8	1.3	2.6
Parathion 15% WP 24 oz.	3594	1.1	0.6	1.4	1.0	0.11
Fungicide only	3340	24.5	3.7	7.8	72.7	
1951: Reed Orchard; Variety, Gallia Beauty; Calyx (May 8); 7 cover sprays (May 16, 25, June 8, 20, July 6, 24, Aug. 13)						*Sept. 18*
CS-708, 25% Em 3 pints	3016	1.7	1.4	0.1	0.8	3.2
CS-708, 18% WP (50% WP after 4th cover) 2 lb.	3588	1.5	0.9	0.3	1.0	2.2
DDT 75% WP 1¼ lb.	3461	0.9	1.0	8.1	2.1	4.0
Parathion 15% WP 24 oz.	2463	3.7	2.7	1.5	1.0	0.08
Fungicide only	2242	60.4	14.8	9.2	47.3	
1951: Crook Orchard; Calyx (May 7); 7 Cover Sprays (May 15, 21, June 15, July 5, 17, and Aug. 13); Variety, Jonathan						*Sept. 2*
CS-708 on tobacco stems 25% WP:						
4 lb.	1476	0.05	0.4	0.05	0.1	10.8
2½ lb.	872	1.3	1.8	0	0.4	6.4
DDT 75% WP 1¼ lb.	1397	1.4	1.9	1.1	1.3	8.1
Parathion 15% WP 24 oz.	1336	3.1	4.4	0	2.0	0.19
Variety, Winesap						*Oct. 1*
CS-708 on tobacco stems 25% WP:						
4 lb.	1775	0.5	1.9	0	3.4	4.4
40 oz.	2307	2.6	2.8	0.02	2.2	2.2
DDT 75% WP 20 oz.	5320	2.3	0.8	0.7	1.0	6.3
Parathion 15% WP 24 oz.	1818	3.4	3.1	0	2.1	0.12
Fungicide only	2183	36.2	13.5	3.7	18.5	

Table 2.—Control of codling moth, Vincennes, Ind., 1951. Field-laboratory test.

Insecticide (Pounds per 100 Gal.)	Per Cent of Larvae Causing Injury After Spraying						Residues (p.p.m.) on Fruit After Spraying		
	12 Days After 5th Cover		Immediately After 6th Cover		13 Days After 6th Cover		12 Days After 5th Cover	Immediately After 6th Cover	13 Days After 6th Cover
	Worms	Stings	Worms	Stings	Worms	Stings			
CS-708 on tobacco stems 25% WP:									
4	9.5	1.5	0.2	0.5	6.2	4.0	8.2	30.2	22.6
2.5	20.5	3.0	3.5	1.2	17.0	5.5	7.7	12.7	8.3
DDT 75% WP 1.25	12.5	4.5	0	0	1.8	1.2	5.0	14.5	8.3
Parathion 15% WP 1.5	9.0	12.7	0	0.2	2.5	1.7	0.2	1.82	0.25
Lead arsenate 3	42.3	7.5	27.8	10.3	33.2	10.8			
Fungicide only	63.8	0	65.0	0	69.5	0			

cent wettable powder per 100 gallons gave nearly as good control as 24 ounces of a 50-per cent TDE wettable powder. CS-708 was less effective when the quantity per 100 gallons was reduced to 2 pounds.

Table 3.—Control of the red-banded leaf roller, Vincennes, Ind., May 21, 1951. Laboratory Tests.

Insecticide (pounds per 100 Gal.)	Leaves Infested Before Spraying		Leaves Infested After Spraying	
	Number of Larvae in Test	Per Cent Mortality After 48 Hours	Number of Larvae in Test	Per Cent Mortality After 48 Hours
CS-708 on tobacco stems 25% WP:				
4	34	94.9	14	100.0
2	—	—	17	88.2
TDE 50% WP 1.5	54	98.1	20	100.0
Unsprayed	18	0	13	15.5

The occurrence of an infestation of the apple aphid, *Aphis pomi*, Deg., in a block of Gallia Beauty trees in which CS-708 was under test indicated that it is not a promising material for controlling apple aphids. On June 5, after the third cover spray, the percentages of infested terminals on trees receiving the indicated treatments follow:

Treatment (Quantities per 100 Gal.)	Per Cent
CS-708, 25% Em, 3 pints	17
18% WP, 2 lb.	56
Parathion 15% WP, 24 oz.	24
DDT 75% WP, 20 oz.	42
Fungicide only	96

The apparent effectiveness of the CS-708 emulsion is attributed to the presence of pine oil in the formulation, although its value in this connection has not been determined.

Peach Pests.—In 1949 CS-674A and CS-645A were tested against the oriental fruit moth in replicated field plots in eastern New York, and in 1950 CS-708 was compared with aldrin, parathion, and EPN in field plots set up in two orchards in Indiana for the control of all major peach pests that attack the fruit.

In a very light infestation in New York, in which only 4 per cent of the fruit became infested in plots sprayed only with fungicides, CS-674A and CS-645A gave good control and compared favorably with DDT and parathion. At 2 pounds per 100 gallons of spray, wettable powders containing 50 per cent of CS-674A, CS-645A, and DDT held the fruit injured at harvest to 0.1, 0.6, and 0.4 per cent, respectively. There was no injured fruit in the plot sprayed with 2 pounds of a 25-per cent parathion wettable powder per 100 gallons.

The results of the tests made in Indiana are given in table 4. CS-708 gave adequate control of the plum curculio, the oriental fruit moth, and the red-banded leaf roller and compared favorably with parathion, EPN, or aldrin, the latter supplemented with DDT. Control of sucking bugs, such as the tarnished plant bug, *Lygus oblineatus* (Say.), and pentatomids, with CS-708 was not satisfactory, but

Table 4.—Control of insects attacking peaches, Vincennes, Ind., 1950. Treatments applied April 17 (full bloom), 26 (petal fall), May 8 (shucks two-thirds off), 16, 25, June 7, and July 14.

Insecticide (Quantities per 100 Gallons)	Average Number of Peaches per Tree	Per Cent of Fruit Injured by—				Residues (p.p.m.) on Fruit at Harvest	
		Sucking Bugs	Plum Curculio	Oriental Fruit Moth	Red-Banded Leaf Roller	Henner Hale	Elberta
CS-708 25% Em 1 qt.	828	16.6	2.5	3.1	0.2	0.8	1.8
Aldrin 25% WP 2 lb. (plus DDT 50% WP in last application 2 lb.)	494	15.4	3.4	2.2	0.6	0.7[1]	0.6[1]
Parathion 15% WP 24 oz.	885	12.5	4.0	0.6	0	0.03	0.02
EPN 25% WP 1 lb.	392	14.6	4.8	1.4	0.1	0.12	0.16

[1] Organic chlorine.

Table 5.—Average rate of weathering of CS-708 residues following last application.

FORMULATION (QUANTITIES PER 100 GAL.)	LAST APPLICATION	INITIAL DEPOSIT (p.p.m.)	PER CENT REDUCTION AFTER—			
			3 Days	7 Days	14 Days	36 Days
		Henners Hale peaches, 1950				
25% Em 1 qt.	July 14	10.2	0	51.0	99.87	99.92
			2 Days	8 Days		
		Gallia Beauty apples, 1951				
25% Em 3 pints	Aug. 13	7.2	0	15.3		55.6
50% WP 2 lb.		5.3	0	0		58.5
						49 Days
		Winesap apples, 1951				
On tobacco stems 25% WP:						
4 lb.	Aug. 13	18.9	0	23.3		76.7
2.5 lb.		10.5	4.8	33.3		79.0

was not much poorer than that obtained with the other insecticides under test.

Pear Psylla.—In 1949 CS-674A and CS-645A were tested in eastern New York against the pear psylla, *Psylla pyricola* Foerst., on two-tree plots of Bartlett pears. On July 14 the plots were treated with sprays containing 1 pint of a 25-per cent emulsifiable concentrate to 100 gallons. Both materials gave good control, the number of nymphs per spur averaging as follows at various intervals after treatment:

	5 days	*14 days*	*27 days*
CS-708	0.1	0	8.0
CS-674A	0.2	0	2.0
Standard cube summer oil	0.1	0.1	14.0
Untreated check	4.7	3.8	12.7

Orchard Mites.—The nitroparaffin compounds have not controlled the European red mite, *Paratetranychus pilosus* (C. & F.), or the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. Heavy populations of these mites have been observed on both apples and peaches sprayed with CS-708. Ordinarily mite populations are heavier on trees that have been sprayed with wettable-powder suspensions than on those that have been sprayed with emulsions. It is possible that the pine oil in the emulsions has some value in mite control. For example, in replicated field plots in 1951 observations showed that on May 16, 24, and June 7 the average numbers of mites per 100 leaves on Gallia Beauty apple trees that had been sprayed on May 8, 16, and 25 were as follows:

	Emulsion	*Suspension*
May 16	670	2204
24	67	1303
June 7	271	7576

RATE OF WEATHERING.—Analyses of residues on replicated samples of peaches and apples at intervals after spraying indicate that deposits of CS-708 are relatively stable and should afford protection for an extended period. Data given in table 5 show that of all the CS-708 formulations tested a 25-per cent wettable powder on tobacco stems gave the heaviest initial deposits.

COMPATIBILITY.—Both emulsions and powdered formulations containing CS-708 were used in combination with tetraethyl pyrophosphate and aramite, as used to control mites. They were also used with wettable sulfur, ferbam, and with N-(trichloromethyl mercapto) tetrahydrophthalimide, as used to control diseases, on several varieties of red apples and peaches without causing visible injury to the fruit or foliage. CS-708 has not been tested on yellow varieties of apples.

SUMMARY.—Experimental insecticide formulations containing CS-645A and /or CS-674A have been tested during the last 3 years in field and laboratory experiments against the major pests of apples and peaches and against the pear psylla. They have repeatedly given adequate control of the codling moth, the plum curculio, the red-banded leaf roller, the oriental fruit moth, and the pear psylla, and inadequate control of the European red mite, the two-spotted spider mite, and the apple aphid. Sprays containing CS-708, a mixture of these materials, also failed to give satisfactory control of the tarnished plant bug and pentatomids that cause much of the injury of peaches known as catfacing, although their use resulted in nearly as great a reduction in

this type of injury as resulted from the use of aldrin plus DDT, parathion, and other organic insecticides tested. CS-708 residues were persistent but did not injure fruit or foliage. CS-708 formulations were compatible with tetraethyl pyrophosphate and aramite, sulfur, ferbam, and with N-(trichloromethyl mercapto) tetrahydrophthalamide.

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Toxicity of Several New Insecticides to Honey Bees[1,2]

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In view of the many inquiries received from farmers and apiculturists regarding toxicity of the newer insecticides and acaricides to the honeybee, *Apis mellifera* L., it seemed advisable to seek information on this subject. A study of the literature revealed many publications dealing with the poisoning of honeybees by arsenicals, fluosilicates, and the like. This literature has been reviewed by a number of authors, including Shaw (1941).

Several dozen articles have been published within the last few years on the effects of the more recently developed pesticides on honeybees. A few of these references follow: Eckert (1948), Eide (1947), Häfliger (1949), Knowlton *et al.* (1950), Linsley & MacSawin (1947), Metcalf & March (1949), Shaw & Bulter (1949), Smith *et al.* (1948), Todd *et al.* (1949), and Weaver (1949). In general, these workers have found, either in the laboratory or in the field, that parathion, hexaethyl tetraphosphate, tetraethyl pyrophosphate, dieldrin, benzene hexachloride, lindane, aldrin, sabadilla, and certain dinitro compounds are highly toxic to honeybees. Most of these workers found DDT to range from moderately to highly toxic to bees in the laboratory. Field results with DDT varied considerably, the effects depending on the time, method, and other conditions of treatment. Most of these workers agree, however, that DDT can be used with safety and to advantage on seed crops and around bees if certain precautionary measures are taken. Some workers found chlordane to be highly toxic to bees, while others found that its toxicity varied considerably from low to high, depending on environmental conditions. These workers have found toxaphene, as well as TDE, methoxychlor, phenothiazine, piperonyl cyclonene, and 2,4-dichlorophenoxy-acetic acid, to be of low toxicity to honeybees, especially in the field.

Because several new insecticides and acaricides have been developed since publication of the reports named above, it seemed advisable to make the following laboratory tests with these newer materials.

MATERIALS AND METHODS.—In the initial tests begun in October, 1950, bouquets of *Lippia lanceolata* flowers were dusted lightly by means of a small hand duster with the following materials (Table 1):[4] parathion; S-(1,2-dicarbethoxyethyl)0,0-dimethyl dithiophosphate (malathon);[5] EPN; DDT; 0,0-diisopropyl 0-*p*-nitrophenyl thiophosphate *Compound 3456*;[5] *p*-chlorophenyl phenyl sulfone and related materials (*Compound R-242*);[6] *p*-chlorophenyl *p*-chlorobenzenesulfonate (*Compound K-6451*);[7] 2-(*p*-tertbutylphenoxy)isopropyl-2′-chloroethyl sulfite, Aramite:[8] and 2,4-dichlorophenyl benzene sulfonate (*Compound 923*).[9]

The treated bouquets were placed in clean screen cages measuring 10×10×14 inches. Honeybees were then collected from *Lippia* flowers in the field by using an aspirator bottle, and were transferred

[1] Paper presented at the meeting of the American Association of Economic Entomologists at Denver, Colorado, December, 1950.

[2] Paper No. 717, University of California Citrus Experiment Station, Riverside, California.

[3] Appreciation is expressed to Milton Crawford and Floyd Hilbig, bee inspectors of the Riverside County Agricultural Commissioner's office, for supplying and assisting with the handling of the bees.

[4] For convenience in referring to dust materials, the common names or the trade designations shown in parentheses are used throughout this paper.

[5] American Cyanamid Co.

[6] *Sulphenone;* Stauffer Chemical Co.

[7] *Ovotran;* The Dow Chemical Company.

[8] Naugatuck Chemical Division of U. S. Rubber Company.

[9] General Chemical Company.

Table 1.—Percentage mortality of honeybees at successive intervals after confinement in cages with bouquets of flowers treated with various dust materials.

Material[1]	No. of Replicates[2]	Per Cent Bees Killed Within—				
		5 Hours	10 Hours	20 Hours	50 Hours	66 Hours
Parathion, 1%	3	100				
Malathon, 1%	6	100				
EPN, 2%	3	100				
DDT, 5%	3	12	35	75	100	
Compound 3456, 5%	21	10	15	33	70	100
Compound R-242, 10%	9	0	7	20	35	55
Compound K-6451, 10%	18	0	7	18	35	53
Aramite, 2%	18	0	15	25	35	40
Compound 923, 10%	3	0	0	5	25	35
Check (untreated)	21	12	20	27	32	40

[1] For description of materials, see section on "Materials and Methods."
[2] At least 20 honeybees in each replicate.

into the cages with the treated flowers. At least 20 bees were placed in each cage. Similar lots of caged bees on undusted flowers were used for checks.

There were 3 replicates for each treatment material in a given experiment and from 1 to 7 experiments (3 to 21 replicates) for each of the different materials tested. Fresh sugar-water solution was available to the bees in all cages. Bee mortality records were taken at intervals of several minutes to several hours, the frequency of the recording depending on the speed of kill obtained with given treatments.

Table 2.—Percentage mortality of honeybees at successive intervals after direct application of various dust materials.

Material[1]	No. of Replicates[2]	Per Cent Bees Killed Within—				
		Minutes				
		10	20	30	40	
Malathon, 1%	9	72	100			
Parathion, 1%	9	10	75	100		
BHC, 2%	9	30	90	95	100	
EPN, 2%	9	5	30	90	100	
Lindane, 1%	9	—	—	100		
Check (untreated)	9	0	0	0	0	
		Hours				
		1	3	6		
Chlordane, 5%	9	32	92	100		
Heptachlor, 1%	9	—	73	100		
Dieldrin, 1%	9	22	63	100		
Aldrin, 1%	9	11	48	100		
Check (untreated)	9	0	0	0		
		Hours				
		1	3	6	12	18
DDT, 5%	21	12	36	60	78	100
Compound 3456, 5%	18	0	26	54	90	100
Toxaphene, 10%	15	3	8	21	89	98
Check (untreated)	21	1	1	2	2	3
		Hours				
		6	12	24	48	72
Compound R-242, 10%	33	12	33	81	88	89
Methoxychlor, 5%	9	17	51	73	73	73
Compound Q-137, 5%	18	—	35	46	70	79
TDE, 5%	9	20	23	42	42	42
Compound CS-645A—CS-674A(1:3), 5%	18	10	16	17	18	18
Aramite, 2%	9	2	2	2	2	2
Compound 923, 10%	9	0	0	0	0	5
Compound K-6451, 10%	9	0	0	0	0	0
Check (untreated)	33	0	0	0	0	0

[1] For description of materials, see section on "Materials and Methods."
[2] At least 20 honeybees in each replicate.

By the middle of November, 1950, it was becoming difficult to collect enough bees in the field for tests, so moderately young bees were obtained in lots of 1 to 2 pounds (4000 to 8000 bees) each from normal, healthy hives in a neighboring apiary. These bees were held in clean screen cages supplied with sugar water, and samples of the bees were drawn off as needed. Given lots of bees were not held longer than a week in these stock cages.

Bouquets of flowers were not used in tests after November 20, 1950. Instead, the different lots of bees were confined in cylindrical screen (18 mesh) cages measuring 3 by 6 inches each, and were dusted in a bell-jar type of duster operated at a 19 to 23-inch vacuum (Farrar *et al.* 1948). In these experiments the following dusting materials were used in addition to those named above (Table 2): benzene hexachloride; lindane; chlordane; heptachlor; dieldrin; aldrin; toxaphene; methoxychlor; 1,1-dichloro-2,2-bis(*p*-ethylphenyl) ethane (*Compound Q-137*;[10] TDE; and a mixture of 1 part 1,1-bis(*p*-chlorophenyl)-2-nitropropane and 3 parts 1,1-bis(*p*-chlorophenyl)-2-nitrobutane (*Compound CS-645A—CS-674A*[1:3]).[11] A 0.25-gram charge of dust was used in each vacuum exposure blast. The dust was allowed to

[10] Rohm and Haas Co.
[11] *Dilan;* Commercial Solvents Corporation.

settle for about 30 seconds. The cages were then removed from the dusting chamber, and the treated bees were transferred to clean 10 by 10 by 14-inch screen cages and handled as described above. Untreated check bees were exposed to the vacuum in the same manner as dusted bees. From 3 to 11 experiments (9 to 33 replicates) were made with each of the different materials used in this manner.

RESULTS.—It is apparent from the data given in table 1 that in the bouquet-dusting tests, phosphate materials such as parathion, EPN, and malathon were highly toxic to the honeybees (100 per cent kill within 5 hours). In most cages most of the phosphate-treated bees were dead within a few minutes. By this test method, DDT and experimental phosphate *Compound 3456* were much slower in action than the three phosphate treatments named above. It also appeared that bees treated with compounds *R-242*, *K-6451* *923*, and aramite survived in about the same proportion as untreated bees. It was thought that the field-collected bees did not make as good test animals as the hive-collected bees used in later tests.

The materials used and the results obtained in tests in which the dust was applied directly to the bees are given in table 2. It is evident from these results that malathon (1 per cent), parathion (1 per cent), benzene hexachloride (2 per cent gamma isomer), EPN (2 per cent), and lindane (1 per cent) were highly toxic to bees. These treatments knocked the bees down so rapidly that many of them were moribund or dead by the time they were transferred to the holding cages. Chlordane (5 per cent), heptachlor (1 per cent), dieldrin (1 per cent), and aldrin (1 per cent) also were quite toxic to the bees (100 per cent kill within 6 hours).

In these tests, DDT (5 per cent), *Compound 3456* (5 per cent), and toxaphene (10 per cent) were moderately toxic to bees, causing kills of 98 to 100 per cent within 18 hours after treatment. Methoxychlor (5 per cent), *Compound Q-137* (5 per cent), and *Compound R-242* (10 per cent) fell into a class of their own, with 73 to 89 per cent kill within 72 hours. Compound *CS-645A—CS-674A*(1:3) (5 per cent) and TDE (5 per cent), which gave 18 and 42 per cent kill within 72 hours, fell into an even lower class in regard to toxicity to bees, while aramite (2 per cent), *Compound 923* (10 per cent), and *Compound K-6451* (10 per cent) appeared to have little if any effect on the bees by the end of 72 hours.

Results with *Compound R-242*, presented in table 2, were obtained with the technical material. Similar tests with the pure material showed it to be practically harmless to honeybees. It is interesting to note that in preliminary tests several of the isomers in the technical material, when used alone, were somewhat toxic to bees, while other isomers were relatively nontoxic. It was also noted that a synergistic effect occurred with combinations of certain isomers found in the technical material.

In preliminary tests in which honeybees were dusted directly, diluents such as pyrophyllite silicate,[12] calcite carbonate,[13] calcium carbonate, magnesium carbonate, and hydrated lime were found to be relatively nontoxic for 72 hours after treatment. An attapulgite clay silicate,[14] however, showed high toxicity to bees at a low humidity and moderate to low toxicity at a high humidity. A mixture of pyrophyllite silicate (90 per cent) and attapulgite clay silicate (10 per cent) was nontoxic to bees. In one test a diatomaceous earth, silicon oxide,[15] was highly toxic within 18 hours after treatment. Sulfur (98 per cent) was also highly toxic to bees within 3 hours, but sulfur can be used with safety in the field because the bees are apparently repelled by it. Dinitro capryl phenyl crotonate[16] (3 per cent) and DMC (3 per cent) were relatively nontoxic for 72 hours after treatment, while bis(*p*-chlorophenoxy) methane (*Compound K-1875*)[17] (5 per cent) was highly toxic within 24 hours after treatment.

It should be noted here that in these laboratory tests the bees were exposed to more severe conditions than they probably would receive in field experiments.

FIELD OBSERVATIONS.—Field observations made in southern California during the last several years on large-scale commercial applications of DDT or toxaphene for pest control on seed alfalfa have shown that these materials can be used without serious loss of bees, especially if applica-

[12] *Pyrolite;* Huntley Industrial Minerals, Inc.
[13] *Atomite;* H. N. Richards Co.
[14] *Attaclay;* Attapulgus Clay Co.
[15] *Celite,* Johns-Manville Co.
[16] *Karathane;* Rohm and Haas Co.
[17] *Neotran;* The Dow Chemical Co.

tions are made early in the morning, when the bee population is at a low level in the field. It is interesting to note here that DDT apparently loses its effectiveness in lygus bug control on seed alfalfa in the interior desert areas of southern California during the period of extremely high temperatures in July, August, and part of September. Toxaphene, since it seems to remain effective for lygus bug control during such extreme temperature conditions, and since it appears to be somewhat less toxic than DDT to bees, is the preferred treatment during hot weather.

Field observations in this same area on commercial applications of dieldrin, parathion, chlordane, and benzene hexachloride have shown that these materials cause heavy loss to honeybees. These data indicate that materials found to be more toxic to bees than DDT, should be used with extreme caution where bees are concerned and that materials found to be less toxic than DDT, may be used with safety.

In several cases where commercial applications of parthion were observed to be killing the honeybees, it was found that the toxicant was carried back to the hives, where brood and other hive bees were killed. Chemical analysis[18] showed from 20 to 100 p.p.m. of parathion in dead bees and brood bees and in the honey in the poisoned hives.

SUMMARY.—In laboratory toxicity tests in which honeybees either were confined in cages with dust-treated bouquets of flowers or were dusted directly, it was found that malathon, parathion, benzene hexachloride, EPN, and lindane resulted in 100 per cent kill of the bees within a few minutes. Chlordane, heptachlor, dieldrin, and aldrin gave 100 per cent kill within 6 hours, while DDT, 0,0-diisopropyl 0-*p*-nitrophenyl thiophosphate (*Compound 2456*), and toxaphene gave 98 to 100 per cent kill within 18 hours. Mexthoxychlor, 1,1-dichloro-2,2-bis(*p*-ethylphenyl)ethane (*Compound Q-137*), and *p*-chlorophenyl phenyl sulfone (*Compound R-242*) were much slower in action, requiring 72 hours to give from 73 to 89 per cent kill, while TDE gave only 42 per cent kill in 72 hours. The compounds aramite, 2,4-dichlorophenyl benzene sulfonate (*Compound 923*), and *p*-chlorophenyl *p*-chlorobenzenesulfanate (*Compound K-6451*), as well as diluents such as pyrophyllite silicate, calcite carbonate, calcium carbonate, magnesium carbonate, and hydrated lime were relatively nontoxic to honeybees. An attapulgite clay silicate was somewhat toxic to bees. Miscellaneous observations on the toxicity of several other insecticides, acaricides, and diluents to honeybees are also reported. Field observations showed that parathion treatments caused poisoning of bees and honey in the hives.

[18] Analysis made by the State Bureau of Chemistry, Sacramento, from samples submitted by Fred Briggs of the Riverside County Agricultural Commissioner's office at Blythe, California.

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Aldrin, Dieldrin and Heptachlor to Control California Melon Insects[1]

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Melons in northern and central California are subject to attack by a number of destructive pests. Important among these are the western spotted cucumber beetle, *Diabrotica undecimpunctata* Mann.; western striped cucumber beetle, *Acalymma trivittata* (Mann.); melon leafhopper, *Empoasca abrupta* DeLong; melon aphid, *Aphis gossypii* Glov.; the agromyzid leaf miner, *Liriomyza subpusilla* (Frost); darkling ground beetles and mites belonging to the "two-spotted" complex.

It is very desirable in the investigation of any insecticide that might be used in the melon insect control program to determine its effect or action upon all the pests involved. The ideal material would be one that controls all of them or failing that, at least would not affect the environment in a manner that would favor an increase in the population of one or more of them.

A satisfactory control program must be based upon effective and economical use of insecticides. If possible, it is desirable to select insecticides that are effective against several pests. Experiments with dieldrin and aldrin against melon insects in 1950, Michelbacher *et al.* (1951), showed that these insecticides were highly effective against the agromyzid leaf miner, *Liriomyza subpusilla*, cucumber beetles, darkling ground beetles and in addition showed considerable promise against the melon leafhopper. Because no effective insecticide for the control of the leaf miner was definitely known, the experiments were conducted primarily to determine the effectiveness of these materials against this pest, and the results obtained with the other insects were incidental. Because serious infestations by the leaf miner are usually not encountered until rather late in the season, the effectiveness of an early application of aldrin and dieldrin against other pests of melons was not fully ascertained. The principal insecticides used during the early stages of growth have been cryolite and DDT. Cryolite, while having no effect upon leafhoppers, has been generally recommended for the control of cucumber and darkling ground beetles. A 3 per cent DDT dust is used when the melon leafhopper makes its appearance in sufficient numbers to justify control. The DDT, of course, results in excellent control of cucumber and darkling ground beetles, and on occasions is used from the start.

In 1951 at Patterson, California, several experiments were conducted to determine the effectiveness of aldrin, dieldrin and heptachlor as compared to DDT in controlling the several pests of melons during the entire growth of the crop. Aldrin, dieldrin and heptachlor were used as emulsions in concentrated sprays and as dusts, while DDT was applied only as a dust. The aldrin stock emulsion contained 2 pounds of active ingredient per gallon, dieldrin 1.5 pounds and heptachlor 2 pounds. The sprays were applied with a ground rig in varying concentrations at approximately 20 gallons to the acre and the dusts with a ground duster having three nozzles to the row and at the rate of from approximately 20 to 30 pounds per acre.

The first experiment was conducted in a honeydew melon field. The plots were approximately one acre in extent and each treatment was replicated twice. The information concerning the treatments and a summary of the results in regard to leaf miner control are given in table 1. At the time of the first application on July 9 the leaf miner infestation was not heavy enough to justify treatment. It was less than one per leaf, and experience has shown that treatment is rarely necessary before the average number of mines per leaf reaches 10 or more. In making surveys the degree of infestation was determined by picking mature

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Table 1.—Treatments and the average number of leaf miners per honeydew melon leaf on the survey dates given. (Treated twice July 9 and 25.)

		Concentrated Sprays[1]					Per Cent Dusts[2]			
		Dieldrin		Aldrin		Hepta-chlor				
Survey Date	Check	0.37 Lb.	0.75 Lb.	0.75 Lb.	1.00 Lb.	1.00 Lb.	Dieldrin 1.5	Aldrin 2.5	Hepta-chlor 3	DDT-S Sulfur 50
July 7	—	0.18	0.25	0.09	0.18	0.18	0.12	0.00	0.09	—
July 12	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July 19	0.43	0.09	0.07	0.04	0.08	0.06	0.13	0.16	0.08	0.52
July 24	0.42	0.07	0.04	0.07	0.13	0.06	0.14	0.15	0.15	0.27
July 30	1.12	0.11	0.05	0.15	0.13	0.10	0.24	0.39	0.27	1.19
Aug. 6	1.13	0.09	0.05	0.05	0.12	0.09	0.10	0.16	0.08	1.03
Aug. 13	2.48	0.08	0.05	0.09	0.06	0.09	0.18	0.20	0.25	2.42
Aug. 20	7.25	0.58	0.43	1.59	1.04	1.06	1.48	1.67	2.26	7.46
Aug. 27	12.31	3.49	2.89	4.99	4.73	3.61	4.67	3.93	7.60	14.48

[1] Expressed as amount of active ingredient applied in 20 gallons of water per acre per application.
[2] First application, rate per acre ranged 16 to 20 pounds; second application approximately 33 pounds per acre.

leaves at random from the center of the plants and counting the mines. Aldrin, dieldrin and heptachlor all resulted in satisfactory control of the leaf miner and the sprays proved to be slightly more effective than the dusts. When the actual amount of insecticide applied is taken into consideration, dieldrin was more effective than either aldrin or heptachlor. A single application of any of the three materials held the leaf miner in check for at least a three week period. The trend of the leaf miner infestation in the check and plots treated with DDT-sulfur closely paralleled one another, indicating a complete lack of control by DDT. On August 27, which was the date of the last survey, the population in each reached a point where injury was starting to become evident, but not of an economic nature.

Although no population counts of cucumber beetles were made, it was obvious that all the insecticides resulted in excellent control of these beetles. It appeared, however, that dieldrin resulted in better protection than either aldrin or heptachlor and it also seemed as if aldrin may have been slightly better than heptachlor.

The leafhopper population trend was followed during the course of the experiment and the results obtained are summarized in table 2. Neither dieldrin, aldrin nor heptachlor proved to be as effective as DDT in controlling this pest. Dieldrin was the only material that gave control approaching that of DDT. With this insecticide the sprays were more effective than the dust. In all treatments there was a decline in the leafhopper population between August 20 and August

Table 2.—Treatments and the average number of melon leafhopper nymphs per honeydew melon leaf on the survey dates given. (Treated July 9 and July 24.)

	Concentrated Sprays[1]					Per Cent Dusts[2]			
	Dieldrin		Aldrin		Hepta-chlor				
Survey Date	0.37 Lb.	0.75 Lb.	0.75 Lb.	1.00 Lb.	1.00 Lb.	Dieldrin 1.5	Aldrin 2.5	Hepta-chlor 3	DDT-S Sulfur 50
July 7	2.60	1.28	2.37	1.83	2.06	2.05	2.08	2.06	—
July 12	2.20	0.97	1.99	2.82	2.38	1.75	2.05	2.60	0.23
July 19	1.34	0.71	2.24	1.77	3.20	2.22	2.34	1.71	0.21
July 24	1.79	0.34	1.93	1.85	2.24	2.02	2.46	2.02	0.00
July 30	0.52	0.11	1.43	1.19	1.71	0.99	1.34	1.03	0.00
Aug. 6	0.35	0.22	1.56	1.34	1.43	0.87	1.17	1.00	0.00
Aug. 13	0.53	0.14	1.89	1.99	2.52	1.30	2.16	1.71	0.00
Aug. 20	1.47	0.54	4.66	5.18	5.09	3.92	5.64	4.12	0.00
Aug. 27	0.11	0.40	0.44	0.55	0.54	0.85	0.58	0.83	0.00

[1] Expressed as amount of active ingredient applied in 20 gallons of water per acre per application.
[2] First application, rate per acre ranged from 16 to 20 pounds; second application approximately 33 pounds per acre.

Table 3.—Treatments and per cent of honeydew melon leaves showing mite infestation on the survey dates given. (Treated twice July 9 and 25.)

		Concentrated Sprays[1]					Per Cent Dusts[2]			
		Dieldrin		Aldrin		Hepta-chlor				
Date	Check	0.37 Lb.	0.75 Lb.	0.75 Lb.	1.00 Lb.	1.00 Lb.	Dieldrin 1.5	Aldrin 2.5	Hepta-chlor 3	DDT-3 Sulfur 50
July 12	0	0	1	0	1	0	0	0	1	2
July 19	1	0	1	0	2	0	2	0	0	0
July 24	1	2	0	1	0	1	2	0	1	0
July 30	1	5	5	1	4	3	2	1	3	1
Aug. 6	0	2	2	6	5	2	5	3	4	0
Aug. 13	2	13	7	10	9	6	10	11	2	0
Aug. 20	4	36	18	11	11	19	14	27	9	6
Aug. 27	6	45	46	26	37	45	34	37	29	9

[1] Expressed as amount of active ingredient applied in 20 gallons of water per acre per application.
[2] First application, rate per acre ranged from 16 to 20 pounds; second application approximately 33 pounds per acre.

27. This was possibly the result of the leafhoppers being killed by a DDT drift when a 90 acre bean field across the road from the experimental area was treated on August 24 with a 5 per cent DDT dust applied by airplane. This illustrates how experimental results can be masked by a treatment applied to another field. It may explain why aldrin looked promising for the control of the melon leafhopper in the 1950 experiments. The fields in which the plots were located were treated with DDT by ground dusters, and it is possible that there was sufficient drift to reduce the leafhopper population in the aldrin treated plots.

As the season advanced, it became apparent that the mite population, principally the Pacific mite, *Tetranychus pacificus* McG., increased more rapidly in the plots treated with aldrin, dieldrin and heptachlor than it did in the check or even in the plots treated with 3 per cent DDT and sulfur. The information on the trend of the mite population in the several treatments is summarized in table 3. This clearly shows the differences that existed. The trend as shown in the table continued and on September 24, about a month after our last counts were made, the mites were so abundant in all the treatments except the checks and the ones receiving DDT and sulfur that the leaves remaining were brown and webbed. The difference was clearly marked right up to the treatment line, and, although mites were present in the checks and DDT-sulfur plots, the population was relatively light and the leaves were not brown and webbed. So destructive were the mites that the 16 acres of the field devoted to aldrin, dieldrin and heptachlor treatments were disked under, while the rest of the field continued in production.

A second experiment was conducted in a field of Persian melons. The leaf miner population at the beginning of this experiment, as in all later investigations, was so large that a count of the individual mines in the leaves was almost impossible. Therefore, on each survey, 100 leaves were picked at random from each plot and placed in one of the following categories:

No—	mines per leaf
1 to 5	mines per leaf
6 to 10	mines per leaf
11 to 20	mines per leaf
more than 20	mines per leaf

In this field there were two applications and each treatment was replicated twice. The treatments, dates of application and a summary of the results on leaf miner control are given in table 4. The percentages of leaves containing more than 10

Table 4.—Treatments and the percentage of Persian melon leaves with more than 10 mines per leaf on survey dates given. Applications July 25 and Aug. 21.

		Concentrated Sprays[1]			Dust 2.5 Per Cent Dieldrin[2]
Survey Date	Check	Dieldrin 0.7 Lb.	Aldrin 1.0 Lb.	Hepta-chlor 1.0 Lb.	
July 25	8	9	17	4	13
July 30	14	23	24	17	12
Aug. 6	6	6	5	4	4
Aug. 13	0	4	3	0	2
Aug. 20	17	6	5	0	2
Aug. 27	72	1	3	0	11
Sept. 4	80	7	6	11	28
Sept. 11	84	16	8	9	15
Sept. 17	80	9	6	4	16

[1] Expressed as amount of active ingredient applied in 20 gallons of water per acre per application.
[2] Approximately 30 pounds per acre per application.

Table 5.—Treatments and per cent of Persian melon leaves showing mite infestation on the survey dates given. (Treated July 25 and August 21.)

Survey Date	Check	Concentrated Sprays[1]			Dust 1.5 Per Cent Dieldrin[2]
		Dieldrin 0.7 Lb.	Aldrin 1.0 Lb.	Heptachlor 1.0 Lb.	
July 25	0	0	0	0	0
July 30	0	0	1	0	0
Aug. 6	0	2	1	0	0
Aug. 13	0	5	0	2	0
Aug. 20	1	5	3	0	0
Aug. 27	3	24	12	10	6
Sept. 4	2	23	24	19	9
Sept. 11	10	47	48	38	38
Sept. 17	31	57	60	73	48

[1] Expressed as amount of active ingredient applied in 20 gallons of water per acre per application.
[2] Approximately 30 pounds per acre per application.

mines per leaf are shown. All treatments when compared to the check all treatments resulted in a marked reduction in the leaf miner population. Although the leaf miner failed to reach a highly destructive level, by the end of the experiment there was a visual difference between the treatments and the check.

All the treatments resulted in adequate control of cucumber beetles. The melon leafhopper never became abundant but from the evidence obtained, dieldrin was the only material that showed promise of approaching satisfactory control of this insect.

The mite infestation was followed, and as in the first experiment, it developed more rapidly in the aldrin, dieldrin and heptachlor treatments than it did in the check. This trend is well illustrated in table 5 where the percentage of leaves infested with mites on the several surveys is given. Unlike the preceding experiment, the mite population never reached a highly destructive level.

A number of other experiments were conducted in which aldrin, dieldrin and heptachlor were used. In all cases the results so closely followed those given in the two preceding experiments that it does not seem necessary to present the experimental results in tabular form. Leaf miner control was good to excellent. Highly satisfactory control resulted with both dusts and sprays. Concentrated sprays of aldrin at the rate of one pound per acre or dieldrin at 8 ounces in 10 gallons of water applied with a boom-equipped airplane were effective. Treatments with these materials at the above mentioned rates, beyond a doubt saved a Crenshaw melon field from serious injury, and effectively checked damage to honeydew melons.

The proper timing of treatments for leaf miner control presents a problem. In a number of fields, as in 1950, it appeared as if the leaf miner was going to be very destructive. However, after an initial rapid increase, the population became static, or in some cases even declined. When this occurred, new growth covered the lower injured leaves and no apparent damage to the melon crop resulted. Among the natural factors limiting damage are natural enemies. Parasites are nearly always present, and frequently in sufficient numbers to control the pest. Often this does not occur until after considerable leaf tissue has been destroyed. As previously reported, Michelbacher *et al.* (1951), the most abundant parasite is a small Eulophidae, *Solenotus intermedius* Gir. No way of accurately predicting the influence of natural controlling factors has as yet been determined. It is certain, however, that control of the leaf miner can safely be delayed until the leaves in the center of the plants or rows show some noticeable injury.

Evidence obtained in all experiments indicated that aldrin, dieldrin and heptachlor resulted in good control of cucumber beetles, but as in the first two experiments, only dieldrin showed any promise in controlling the melon leafhopper.

In none of the experiments did the melon aphid population develop to a destructive level. However, without exception, the melon aphid population was less in plots treated with aldrin or dieldrin than it was in untreated plots or those treated with DDT. These observations are in agreement with those obtained in 1949 (Michelbacher & Middlekauff 1950), and indicate that these insecticides exert some control or at least do not favor an increase in the aphid population. The aphid population in most of the experiments where heptachlor was used was so limited that no definite statement concerning its effect upon the aphid can be made. What evidence was obtained indicated that heptachlor did not result in an increase in the aphid population.

Wherever aldrin, dieldrin or heptachlor were applied, there was an increase in the mite population. The seriousness of the infestation appeared to be correlated with

the time of the season that the insecticides were applied. Usually the later the application, the less the injury. Thus less destruction from mites would be expected from September applications than from those made in July or August.

In one experiment, actual counts of mites from leaf samples were made. Large blocks of a honeydew melon field were treated with dieldrin and aldrin on August 20. The blocks were separated from one another by a DDT-sulfur treated strip 18 rows in width. By September 12 it was apparent that mites were increasing more rapidly in the dieldrin and aldrin plots than in the DDT-sulfur treatment. Samples for mite counts were obtained by picking 25 mature leaves at random from the center rows of each treatment. On each leaf three random impressions were made with a number 10 cork borer (15 mm. in diameter) and the mites in all stages of development, except the egg, in these marked areas were counted.

On September 12, one half of the dieldrin plot was treated with an aramite emulsion spray applied with a ground rig at the rate of one pound (2 quarts) of aramite [beta-chloroethyl-beta-(paratertiary butyl phenoxy-alpha-methylethyl sulfite], in 20 gallons of water per acre. The stock emulsion used contained 2 pounds of aramite to the gallon.

The treatments, information concerning applications, and the average number of mites per sample are given in table 6. The data clearly show that the mite population increased much more rapidly in the dieldrin and aldrin treatments than it did in the plot receiving DDT-sulfur. The latter, however, showed a higher popualtion density on the last survey, which was conducted on October 8. This can be explained by the fact that leaves in the dieldrin and aldrin treatments had been destroyed to a point where they could no longer support a large population. The chlorophyll was largely destroyed and the leaves for the most part were badly webbed. The control of the mite with the aramite spray was satisfactory when it is considered that it was applied in only 20 gallons of water per acre. Although considerable injury from mites resulted in the dieldrin and aldrin plots, this occurred so late in the development of the crop that little actual damage to the melons resulted.

Table 6.—Average number of mites per sample on the survey dates given.

Survey Date	Treatment, Approximate Pounds per Acre and Date of Application[1]			
	Check[2]	Dieldrin 0.5 Lb.	Dieldrin 0.5 Lb. Aramite 1.0 Lb.	Aldrin 1.0 Lb.
Sept. 12	0.37	6.61	—	5.82
Sept. 17	3.58	26.57	4.57	13.40
Sept. 24	17.64	32.10	6.45	30.20
Oct. 8	27.23	5.41	10.12	22.60

Dieldrin and Aldrin Applied Aug. 20, Aramite Sept. 12.
[1] Applied in approximately 20 gallons of water by ground rig.
[2] Received an early dusting of 3% DDT-50% sulfur at approximately 30 pounds per acre.

Aldrin, dieldrin and heptachlor are all toxic to bees. In order to minimize injury to them, most applications were made in early morning before the flowers opened and before bees began visiting the fields. Although rather large acreages were treated, there was little evidence to indicate that many bees were killed by any of the treatments. However, this is a problem that is in need of further investigation. This is particularly true if any of the above insecticides should come into wide use on melons.

Neither aldrin, dieldrin or heptachlor have been released for the control of melon insects. Residue studies are now being conducted and it is believed that no serious residue problem is likely to be encountered. Yet, until this is definitely known and until they have been certified for use on melons, aldrin, dieldrin and heptachlor can not be recommended in the melon insect control program.

SUMMARY AND CONCLUSIONS.—Dieldrin, aldrin and heptachlor are all effective against the agromyzid leaf miner, *Liriomyza subpusilla* (Frost). When dosage is taken into consideration, dieldrin is superior to the others. Satisfactory control resulted with a dosage of 8 to 12 ounces per acre, while with aldrin and heptachlor 12 to 16 ounces is needed. A single treatment should remain effective for a period of at least 3 weeks, and sprays are somewhat more effective than dusts. While DDT exerts no control of the leaf miner, there is little to indicate that it results in an increase in the leaf miner population. Investigations to date show that environmental conditions are far more important in increasing the leaf miner population than are any of the insecticides used in the melon insect control program.

Dieldrin, aldrin and heptachlor all result in highly satisfactory control of cucumber beetles, but only dieldrin shows promise in controlling the melon leafhopper, *Empoasca abrupta* DeLong. Dieldrin and aldrin may tend to suppress the melon aphid, *Aphis gossypii* Glov., while heptachlor at least does not appear to result in an increase in the population. All three insecticides have a tendency to increase the mite population, principally the Pacific mite, *Tetranychus pacificus* McG., and serious damage to the crop may result where applications are made during July and August. There is but little question that the mite problem could be largely avoided if these insecticides were used in combination with sulfur. Such a practice would be feasible only where these insecticides are used to treat honeydew melons for this is the only variety which is not severely injured by applications of sulfur. Where it might be desirable to use these insecticides on other varieties of melons and a serious mite infection threatens, there is reason to expect some of the newer acaricides such as aramite or Ovotran, [p-chlorophenylphenylchlorobenzene sulfonate] might be used successfully to control them. In fact, a number of experiments, which will be reported elsewhere, have been conducted in which both of these materials have given excellent control. Also, under some conditions, aldrin, dieldrin or heptachlor might be applied without resulting in any noticeable increase in the mite population. Applications made during September and later are not likely to result in destructive populations.

After 2 years of extensive investigations it appears that the principal use of aldrin, dieldrin and heptachlor in the melon insect control program might well be limited to those cases where the leaf miner becomes a problem. In general, other more effective insecticides are available for use against the other destructive pests of melons.

Because the leaf miner population is frequently checked by natural controlling factors, it is difficult to say at just what level of infestation control measures should be applied. It is certain that no treatment need be given before some injury is noticeable on the older center leaves of the plant.

Of the three insecticides, dieldrin at the present time appears to show the most promise, because it is effective at lower dosages and against more melon insects, particularly the melon leafhopper, than are the other two.

No serious injury to bees was observed where dieldrin, aldrin or heptachlor were applied in early morning before the blossoms opened and bees began entering the fields. However, it is recognized that this subject is in need of more study and this is particularly true if any of these insecticides should be widely used. An entirely different situation might be presented if hundreds of acres are treated instead of from 10 to 25 as was the case in the experiments reported in this paper.

No recommendations for the use of dieldrin, aldrin or heptachlor in the melon insect control program can be made, because at the present writing none of these insecticides has been released for use on melons. It hardly seems, however, that any of them should result in a serious residue problem.

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C. K. DORSEY TO WEST VIRGINIA

Dr. C. K. Dorsey has been appointed Professor of Entomology at West Virginia University, Morgantown. He will assume the duties of L. M. Peairs who has retired, effective July 1, 1952, after more than forty-five years of teaching, forty years of which were spent at West Virginia University.

Control of Leaf Miners and Other Insect Pests of Asters

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The agromyzid leaf miner, *Liriomyza langei* Frick is the most serious insect pest of asters, an important cut flower crop, in the Los Angeles area. According to Frick (1951), this species, which he has described as new has been confused with *Liriomyza flaveola* (Fallen) by Lange (1945), Smith & Lange (1946), and Jefferson & Pence (1949), and with *Liriomyza orbona* (Meigen) by Melander (1913), Frost (1943) and Lange & Smith (1947).

On asters the mines of *Liriomyza langei* are mostly basal on the leaves and extending down the petiole. They are usually serpentine, but in heavy infestations there may be many larvae in a leaf with the mines running together to form a large blotch. During the warm summer months the life cycle may be completed in 3 to 4 weeks.

In the Los Angeles area asters are usually grown in sandy soil with overhead sprinkling being employed. During the hot summer weather they may be watered every 2 or 3 days. The frequent irrigation required may be an important factor in control of the leaf miner as insecticides, particularly dusts, may be washed off soon after application.

Lange & Smith (1947) found chlordane to be more effective than DDT, benzene hexachloride, DDD and methoxychlor against *Liriomyza flaveola* on peas. In preliminary tests on asters, Jefferson & Pence (1949) obtained satisfactory control with chlordane and benzene hexachloride. Wolfenbarger (1949) in tests against a closely related species, *Liriomyza pusilla* (Meig.) found parathion to be most effective of the materials tested.

While the experiments described in this paper were primarily for the control of *Liriomyza langei*, data was also taken on the effectiveness of the various insecticides against whiteflies and leafhoppers. Both the green-house whitefly, *Trialeurodes vaporariorum* (Westwood), and the iris whitefly, *Aleyrodes spiraeoides* Quaintance, are found on asters. While several species of leafhoppers are found on asters, the most common ones are *Empoasca abrupta* De L. and *Thamnotettex montanus* Van D.

Methods and Materials.—Randomized block designs were used in all field experiments. Analysis of variance was applied to all data except in 1950 when group comparisons (Snedecor 1946) were used. The plots were 10 to 12 rows wide and 30 to 40 feet long except in 1950 when larger plots were used.

Dusts were applied with a rotary-type hand duster. The parathion and ethyl p-nitrophenyl thionobenzenephosphonate dusts were applied at approximately 20 pounds per acre, and the toxaphene and benzene hexachloride dusts at 35 to 45 pounds per acre. Sprays were applied with a small power sprayer at 300 pounds pressure using a gun with a No. 3 disc. Insecticide treatments usually were begun shortly after the plants were pinched back and were discontinued at the time cutting began.

The benzene hexachloride dust contained 0.75 per cent of the gamma isomer and was composed of 6.25 pounds of a 12 per cent gamma wettable powder,[1] 31.25 pounds of diatomaceous earth[2] and 62.5 pounds of pumice.[3] The 10 per cent toxaphene dust contained 25 pounds of a 40 per cent wettable powder and 75 pounds of pumice. The 50 per cent chlordane emulsifiable concentrate also contained 42 per cent by weight of an aromatic solvent,[4] and 8 per cent of an emulsifier composed of polyoxyethylene sorbital esters of mixed fatty acids.[5] Other materials used were various formulations of toxaphene and chlordane, S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate,[6] diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol,[7] ethyl p-nitrophenyl thionobenzenephosphonate,[8] and parathion.[9]

[1] Furnished by Pennsylvania Salt Mfg. Co.
[2] *Celite No. 209*, Johns-Manville Co.
[3] *Frianite M3x*, California Industrial Minerals Co.
[4] Technical chlordane and Aromatic Solvent 42 furnished by Julius Hyman & Co. and Shell Oil Co., respectively.
[5] Atlox 1045A, furnished by Atlas Powder Co.
[6] Compound 4049, furnished by American Cyanamid Co.
[7] Systox, furnished by Geary Chemical Corp.
[8] EPN-300, furnished by E. I. duPont de Nemours and Co.
[9] Experimental formulations were furnished by the following: American Cyanamid Co., parathion 25 per cent wettable, powder, parathion 1 per cent dust (1949); Stauffer Chemical Co.

The effectiveness of the insecticide treatments was determined on the basis of leaf injury for the leaf miner and leafhoppers, and on the number of larvae and pupae found for whiteflies. Counts were made in the 4 center rows of each plot at the time cutting began. In the leaf miner counts all the mines in the leaves of 50 flower stems taken at randon were counted, except in 1949. Because of the difficulty of determining accurately the number of mines in the heavily infested bottom leaves, the 1949 counts were made only on the leaves in the upper 12 inches of each stem. In the leafhopper and whitefly counts, 50 leaves were taken at random from each plot and examined in the laboratory.

1948 TESTS.—The 1948 tests consisted of an experiment with 9 treatments replicated 6 times. There was no check plot in 1 block and the missing plot technique (Snedecor 1946) was used in analyzing the data.

The sprays were applied at 2 week intervals and the dusts at weekly intervals beginning April 26. There were a total of five spray applications and nine dust applications, except for parathion. Because of foliage injury the parathion spray was omitted after the third application.

Results are shown in table 1. Excellent control of the leaf miner was obtained with all insecticide treatments. Analysis of the data showed no significant differences among the toxaphene, chlordane and wettable benzene hexachloride treatments, or between the wettable benzene hexachloride and the benzene hexachloride dust. However, significant differences occurred between the benzene hexachloride dust and several other treatments.

While parathion was significantly less effective than the other insecticide treatments, this probably was due to fewer applications, and from the practical standpoint, good control was obtained.

The checks were not included in the analysis of the leaf miner data and significant differences among blocks did not occur. However, there was considerable variation in infestation among the check plots. The most heavily infested ones were those adjoining later plantings, but when these plantings were sprayed with chlordane toward the end of the experiment the infestation decreased. No differences in infestation were observed in treated plots adjoining the other plantings and those throughout the rest of the experimental planting.

The toxaphene and parathion sprays and the benzene hexachloride dust were the most effective treatments for leafhoppers, and the differences between these materials and all other insecticide treatments were highly significant. More injury occurred in the chlordane and wettable benzene hexachloride treatments than in the checks.

Parathion appeared to be the most effective treatment for whiteflies although the differences between it and toxaphene, the benzene hexachloride dust and chlordane at 1.5 pounds per 100 gallons were not significant. The other chlordane treatments were not significantly better than the checks. Significant differences among blocks occurred.

1949 TESTS.—A severe leaf miner outbreak occurred in August of 1949 and a heavy infestation developed in an experiment being conducted at that time. The materials used in this experiment were toxaphene, chlordane and lindane at 1.0, 1.0 and 0.25 pound per 100 gallons respectively. There were 3 spray applications at intervals of 2 weeks. None of the materials gave effective control of the leaf miner.

Another experiment was begun on August 15 in a heavily infested field. Including the checks there were 7 treatments replicated 4 times. Six spray applications and 13 dust applications were made between August 15 and September 19.

Results are shown in table 2. In spite of the frequent insecticide applications the lower leaves were heavily infested. Since it was difficult to make accurate counts in leaves in which the mines formed blotches, counts were made in the leaves of the upper 12 inches of each flower stem. Analysis of the data indicated no significant differences among insecticide treatments but highly significant differences between the checks and insecticide treatments. Significant differences among blocks were not shown.

parathion 1 per cent dust (1950); Hercules Powder Co., toxaphene 50 per cent emulsifiable concentrate; Chipman Chemical Co., toxaphene 60 per cent emulsifiable concentrate and 40 per cent wettable powder; Dow Chemical Co., chlordane 40 per cent emulsifiable concentrate and 50 per cent wettable powder; Pennsylvania Salt Manufacturing Co., benzene hexachloride 12 per cent gamma isomer wettable powder.

Table 1.—Results of insecticide treatments for control of leaf miners, leafhoppers and whiteflies on asters, 1948.

Treatment	Pounds Toxicant per 100 Gallons	Leaf Miner	Leafhoppers	Whiteflies
		No. of Mines in Leaves of 50 Stems	Per Cent Leaves with more than 100 Punctures	No. Larvae & Pupae per 50 Leaves
Toxaphene, 50% emulsifiable	1.25	2.2	2.0	17.2
Chlordane 50% emulsifiable	1.5	2.8	48.0	21.5
Chlordane 50% emulsifiable	1.0	4.7	54.7	35.7
Chlordane 40% emulsifiable	1.0	3.3	61.3	37.8
Chlordane 50% wettable	1.0	2.8	55.0	30.3
BHC 12% gamma isomer, wettable	0.24	5.5	71.7	24.5
BHC dust, 0.75% gamma isomer	—	8.8	14.3	20.0
Parathion 25% wettable[1]	0.25	24.7	6.0	7.8
Check	—	305.0[2]	44.7	39.7
Minimum significant difference				
5% level		4.3	24.6	14.6
1% level		5.7	33.0	19.6

[1] Only 3 spray applications.
[2] Check not included in analysis.

While the control obtained could not be termed satisfactory, the insecticide, treatments definitely were of value and the infestation apparently was checked after several weeks. Since the lower leaves, which were severely damaged, are stripped off at cutting, there was little loss except in the check plots.

The parathion-toxaphene dusts, parathion-wettable benzene hexachloride sprays and the toxaphene spray were the most effective treatments against leafhoppers. Significant differences were not indicated among these treatments. Since poor control was obtained with the wettable benzene hexachloride the previous year, the effectiveness of the parathion-wettable benzene hexachloride treatment is attributed mainly to the two parathion sprays. Some control was obtained with the chlordane treatments in contrast to the results of 1948. Significant differences among blocks were indicated.

While analysis of the whitefly data gave an "F" value slightly below that required for significance, the trend of the results was similar to those obtained in 1948 with those treatments which included parathion apparently being the most effective. Significant differences among blocks were not indicated.

Table 2.—Results of insecticide treatments for control of leaf miners, leafhoppers and whiteflies on asters, 1949.

Treatment	Pounds Toxicant per 100 Gallons	Leaf Miner	Leafhoppers	Whiteflies
		No. of Mines in Leaves of 50 Stems[1]	Per Cent Clean Leaves	No. Larvae & Pupae per 50 Leaves
Toxaphene 60% emulsifiable	1.25	131.3	69.2	8.0
Chlordane 40% emulsifiable	1.0	106.3	48.0	14.8
Chlordane 40% emulsifiable	2.0	152.5	47.5	9.1
Parathion 1% dust[2]				
Toxaphene 10% dust		128.3	82.2	3.0
Parathion 25% w.p.[3]	0.15			
BHC 12% gamma w.p.	0.24	47.5	64.1	4.3
BHC dust, 0.75% gamma isomer		126.3	49.5	17.0
Check		364.3	30.0	34.0
Minimum significant difference				
5% level		129.8	17.5	—
1% level		177.8	24.0	—

[1] Counts were made in leaves of upper 12 inches of the stems.
[2] Four parathion dust applications, nine toxaphene dust applications.
[3] Two parathion spray applications, four benzene hexachloride spray applications.

Table 3.—Results of parathion and ethyl p-nitrophenyl thionobenzenephosphonate treatments for control of leaf miners, leafhoppers and whiteflies on asters, 1950.

Treatment	Leaf Miner				Leafhoppers	Whiteflies	
	Mines in Leaves of 50 Stems		Per Cent Larval Emergence		Per Cent Clean Leaves	Larvae & Pupae per 50 Leaves	
	I	II	I	II	II	I	II
Parathion 1% dust	39.0	15.5	6	8	92	2	2
Ethyl p-nitrophenyl thionobenzenephosphonate 2% dust	287.5	97.0	38	38	94	37	63
Ethyl p-nitrophenylthionobenzonephosphonate 27% w.p.[1]	110.0	—	48	—	—	212	

[1] 1 pound of the wettable powder to 100 gallons.

1950 TESTS.—In 1950 ethyl p-nitrophenyl thionobenzenephosphonate was compared with parathion for control of the leaf miner. The experiment was designed for analysis by group comparison and larger plots were used than in previous years. Two adjoining plantings were used, the first receiving 7 dust applications between July 24 and August 29, and the second 4 dust applications between August 15 and September 15. There were 2 parathion dust plots and 2 ethyl p-nitrophenyl thionobenzenephosphonate dust plots in each planting. The first planting also included two ethyl p-nitrophenyl thionobenzenephosphonate spray plots which received 3 applications. The spray plots were included primarily for information on plant tolerance and the data from them were not analyzed statistically.

Results are shown in table 3. The 1 per cent parathion dust was more effective than the 2 per cent ethyl p-nitrophenyl thionobenzenephosphonate dust and the "t" test indicated that the difference was highly significant. Analyses of the data for each planting and of combined data for both plantings gave highly significant differences in all cases. Table 3 also indicates that the parathion dust was more effective against the larvae in the leaves than the ethyl p-nitrophenyl thionobenzenephosphonate dust.

The parathion dust was also more effective against whiteflies than the ethyl p-nitrophenyl thionobenzenephosphonate dust and the difference was highly significant.

1951 TESTS.—The 1951 tests consisted of three treatments replicated 4 times. The object of the experiment was to compare S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate and the diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol with parathion.

Parathion 25 per cent wettable powder was used at 0.15 pound of actual parathion per 100 gallons of spray. The S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate was a 16.25 per cent wettable powder and was used at 0.65 pound of active ingredient per 100 gallons but the concentration was reduced to 0.49 pound in the second spray because of foliage injury. The diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol was a 32.1 per cent emulsifiable concentrate and was used at 0.375 pound of the active ingredient per 100 gallons.

Foliage injury resulted from the first parathion spray and the second spray was omitted. Since the leaf miner did not appear to be building up in any of the plots, no more parathion sprays were applied and these plots were left as checks. There were 4 spray applications of S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate and 2 of diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol.

When cutting began there were so few leaf mines in the plots that counts were not made. Analysis of the whitefly data gave an "F" value that was not significant. The following results were obtained against leafhoppers:

	Per Cent Clean Leaves
Parathion, 1 spray	74.0
S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate, 4 sprays	86.5
Diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol, 2 sprays	89.0

While the leafhopper population was light throughout the experimental plots and the rest of the field, analysis of the data showed that the single parathion spray was significantly less effective than the other 2 materials. Significant differences among blocks did not occur.

DISCUSSION.—As a result of the control obtained in 1947 with chlordane and benzene hexachloride against the leaf miner, most growers used one or the other of these materials successfully in 1948. Sprays generally were applied at 2 week intervals and dusts every 7 to 10 days. In August of 1949 when the outbreak occurred, some growers checked the infestation by applying the materials more frequently. Others tried parathion dusts which proved to be much more effective.

The lack of effectiveness of chlordane, toxaphene and benzene hexachloride in 1949 in contrast to 1947 and 1948 is not easily explained. At one time it was thought that a different species of leaf miner might be involved, but examination by Dr. Kenneth Frick of material collected from 1947 through 1950 showed that it was *Liriomyza langei* in all cases.

In the tests in 1949, chlordane, toxaphene and benzene hexachloride appeared to be effective against the adult leaf miners but their residual effect apparently was much shorter than in previous years. The day after the application of these materials few live adults could be found in the plots and many dead ones were found on the ground. However, 5 days later the adults would again be very numerous in the plots. As a result, the interval between applications was decreased, the sprays being applied every 5 days and the dusts every 2 or 3 days.

Parathion had been tested in 1947 and 1948 with promising results. However, because of the health hazards involved with its use, and the susceptibility of asters to injury, its use by growers was not encouraged. During the latter part of 1949 and in 1950, there were reports of a number of cases of illness which were attributed to parathion.

In 1950 many growers used only parathion. Others began the season using chlordane, toxaphene or benzene hexachloride, but when the leaf miner gradually began to build up in the fields they shifted to parathion. In 1951 parathion was in general use and damage from the leaf miner was slight.

Parathion was also the most effective material against leafhoppers and whiteflies, the other principal pests of asters. Toxaphene also gave good control of leafhoppers and reduced whitefly populations. Chlordane and benzene hexachloride were less effective against leafhoppers and whiteflies.

On the basis of leaf injury, the ethyl p-nitrophenyl thionobenzenephosphonate spray appeared to be more effective against the leaf miner than did the ethyl p-nitrophenyl thionobenzenephosphonate dust. However, a greater percentage of larvae emerged from the leaves in the sprayed plots. This may have been due to the longer interval between applications since a 100 per cent kill of the larvae was obtained with the spray in laboratory tests.

While no conclusions could be drawn as to the effectiveness of S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate and diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol against the leaf miner, both materials showed promise in laboratory tests.

No phytotoxic effects were observed from chlordane, toxaphene, benzene hexachloride, ethyl p-nitrophenyl thionobenzenephosphonate or diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol. Injury resulted from parathion sprays containing 0.25 pound of actual parathion per 100 gallons, and to some extent from sprays containing 0.15 pound. Dusts containing 1 per cent parathion were very likely to cause injury if applied in excess of 20 pounds per acre. Sprays containing 0.65 pound of actual S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate caused injury, but when the concentration was reduced to 0.49 pound no further injury was observed.

SUMMARY.—The leaf miner *Liriomyza langei* Frick is the most serious insect pest of asters in the Los Angeles area. Parathion was more effective against the leaf miner than chlordane, toxaphene, benzene hexachloride and ethyl p-nitrophenyl thionobenzenephosphonate. Whiteflies and leafhoppers were also effectively controlled by parathion.

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The Importance of Coordinating Applied Control and Natural Control of Forest Insects[1]

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Although most forest insects rarely cause economic damage, there are a number which at times increase to epidemic proportions causing severe losses. Craighead & Middleton (1930) list about 100 such species from the United States. The extent of the applied control being practiced against these economically important species has increased tremendously within the past few years. This is largely due to the development of new and more powerful insecticides, together with the development of modern methods of application. Such work has also gained great impetus from the passage of the Forest Pest Control Act. This act authorized a program of annual forest insect surveys, which are made for the express purpose of detecting incipient outbreaks so that control measures can be applied before serious damage has been done. It also authorizes the expenditure of federal funds for control work on State and private lands, provided the work is approved by the Federal government and the owners contribute part of the cost.

With so much emphasis being placed on the detection of insect outbreaks and the application of control measures, it is easy to lose sight of the fact that most forest insects never become economically important and that most of our serious pests remain at very low levels for long periods between outbreaks. Many natural control factors, including parasites, predators, disease, adverse weather conditions, and limited food supplies, combine to bring about this situation. It seems only logical, therefore, to attempt to estimate the control that can be expected from these natural factors whenever applied control is contemplated, and, in so far as possible, plan to coordinate the two. This is by no means an original idea, but it does seem particularly applicable to forest insects. Generally speaking, relatively large numbers of forest insects can be present without causing serious economic losses. Unless a particularly vulnerable portion of the tree, such as a white-pine leader, is destroyed, serious damage rarely occurs except during heavy outbreaks that last for more than one season. This means that usually many important natural control factors, such as parasites and predators, have an opportunity to build up to the point where they are economically important before heavy losses occur. It also means that as a rule there will be time to estimate the value of natural control factors before engaging in large-scale control operations.

Coordination of natural and applied control will differ considerably with different types of forest insects. In all cases,

[1] This paper was presented at the meeting of the Association of Economic Entomologists, at Cincinnati, Ohio, December, 1951.

though, certain requirements would seem necessary, such as (1) an estimate of the insect's abundance, (2) an evaluation of the principal natural control factors in operation, (3) a decision as to when and where to apply control measures, and (4) a choice regarding the best control measures for a particular project.

Estimates of an insect's abundance are, of course, basic to any planned control work. Such estimates are usually made by carefully planned surveys throughout the affected area. Often it is impossible to estimate the number of insects present per unit area more than once before engaging in large-scale control operations, and sometimes further observations are unnecessary. On the other hand, if further counts could be made it should be possible to determine gross fluctuations in population levels at various developmental stages, and estimate the effect of extensive natural control factors, such as winter mortality. An excellent example showing the value of such observations occurred in 1949. Plans had been made to treat a severe outbreak of the mountain pine beetle, *Dendroctonus monticolae* Hopk., in the northern Rocky Mountain region at a cost of $100,000. In the previous winter low temperatures following an abnormally warm period killed practically all the overwintering brood, making control work entirely unnecessary. Such an example may be unusual, but it illustrates the importance of making observations on natural control factors.

Surveys to determine the abundance of a pest might readily be expanded to provide data on natural control factors, such as parasites and predators, if collections for dissections and rearings could be made at the time survey work is done. Collection of material for this purpose would require painstaking handling under laboratory conditions, and a great deal of detailed work would be involved, but it should provide a basis for evaluating the amount of natural control exerted by these important agents. Probably the most satisfactory method for obtaining these data would be through the establishment of regular collection points in the infested area where several collections could be made annually.

The decision as to when and where to apply control measures should involve an estimate of the amount of natural control, and also the amount of damage to be anticipated. Some insects, such as bark beetles—perhaps our worst forest pests—sometimes increase to epidemic proportions very suddenly when an abundant food supply becomes available. This may be caused by a serious blow-down, or similar happening. In any event, the pest is present in such numbers that only an unusual set of circumstances could be expected to check its increase. Under such conditions an immediate resort to applied control is clearly indicated. At times, though—and this is more generally true of defoliators than of bark beetles—it may be advisable to delay applied control, even if some trees are killed, if by so doing natural control factors are able to build up to the point where they will later effect general control over a large area. Unfortunately, most large-scale control operations unavoidably destroy large numbers of natural control agents. Many are killed outright. All have their immediate source of increase destroyed. Ullyett (1947) has pointed out that, when an infestation is high, parasites and predators have their greatest chance of increasing to the point where they will be able to control the host insect in the future. He even believes it unwise to apply an insecticide at this time. The host population may be largely destroyed, but the maximum harm will be done to the parasites and predators. Ullyett's investigations were made on a crop insect, *Plutella maculipennis* Curt., and he would perhaps modify his conclusions somewhat regarding insects which kill trees during heavy outbreaks. Nevertheless, his conclusions seem amply justified where natural control factors account for a high percentage of mortality, and the host population is not increasing rapidly enough to threaten the destruction of a large amount of valuable timber. A situation of this sort occurred during the recent outbreak of the spruce budworm in New York. The outbreak arose very quickly. It was first observed in 1945 and by the end of the 1948 season balsam trees in many localities were severely defoliated. It seemed probable that another season of heavy feeding, certainly two seasons, would cause considerable tree mortality. Fortunately, there was such a drop in budworm populations during 1947 that large-scale spraying was not even contemplated. However, had the area been sprayed in 1946 or early in

1947, the money and effort certainly would have been wasted.

The question as to what proportion of the affected area should be treated and what could safely be left also calls for careful study. Control by natural factors on part of an affected area is probably much more common than suspected. In bark beetle outbreaks the percentage of parasitization or predator activity may be especially high on certain trees. Rust (1933) has called attention to the importance of mites in the destruction of various species, and De Leon (1935) has shown that parasitization of the mountain pine beetle frequently runs as high as 80 or 90 per cent. These facts indicate the possibility of selecting trees in which natural enemies are especially abundant and leaving them untreated during control operations. In outbreaks of defoliators it is frequently possible to treat only that portion of the affected area where the trees will die after one more defoliation. In 1947 a heavy outbreak of the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD. on 400,000 acres in Idaho was sprayed with DDT from the air. Complete control was effected. About 140,000 acres almost completely defoliated in 1946 would undoubtedly have been defoliated again, and the trees killed, had not the spray been applied. On the other hand, there seems to be little doubt that natural control brought about by parasites and disease would have completely suppressed the outbreak over the entire area (Evenden *et al.*, 1947) by late August. Actually that is what occurred in two large check areas. Apparently, then, the control work carried out on 260,000 acres could have been omitted.

The best method of control against a particular pest may prove to be an insecticidal spray or some silvicultural practice. In any case the best method will be based on the bionomics of the pest. It should also be based on the bionomics of the natural control factors affecting the pest. Pickett (1949), Lord (1947), and others have called attention to the fact that certain chemicals may be so destructive to important natural control factors that their use actually results in an increased host population. In forest insect work, where an insecticide is seldom used on the same area for more than one season, the problem is somewhat different than for crop or fruit pests. Nevertheless, careful observations should be made on the effect of different insecticides on parasite and predator abundance, particularly in large forested areas. A check is now being made on parasitization in areas sprayed for the control of the spruce budworm in Oregon during the past three seasons.

Although not generally thought of as applied control, certain silvicultural practices may be very effective control measures. Removing high-risk bark beetle trees, and planting certain mixtures would come under such a classification. Most good silvicultural practices seem to be, by their very nature, favorable to the increase of natural factors, and, therefore, probably preferable to any other method.

Eventually a close coordination will certainly develop between applied and natural control in forest insect work. Applied control is so expensive that any way in which it can be kept to a minimum is bound to be utilized. It is of the utmost importance, though, that both methods of control be studied at the same time on the same project. Otherwise much valuable time and money is certain to be wasted.

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Temperature and the Action of DDT on the American Roach

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Increased toxicity of topical applications of DDT at low temperatures has been reported for several insects. *Blatella germanica* (L.) (Guthrie, 1950), *Musca domestica* (L.) (Hoffman and Lindquist, 1949), *Triboleum castaneum* Hbst. (Potter & Gillham, 1946; Pradhan, 1949), *Melophagus ovinus* (L.) (Hoffman, *et al.* 1949), *Aëdes aegypti* (L.) (Fan *et al.*, 1948), and *Apis mellifica* (L.) (Hafliger 1948) show increased susceptibility to contact applications of DDT at low temperatures. The consistency observed in the effects of temperature with all tested insects has led to generalizations that attempt to explain the negative temperature coefficient of action of DDT. Pradhan (1949) suggested, in the case of topical applications, that the increased effectiveness of DDT at low temperatures is the result of the effects of temperature on the opposing factors of penetration (including "pick-up" of DDT from surfaces and the subsequent absorption of DDT) and physiological resistance (including the detoxification or elimination of DDT) of the insect.

In the absence of analytical data on the rates of penetration and detoxification of DDT, the generalization of Pradhan appears to reconcile the results of most investigations. Fan *et al.* (1948), however, proposed a different explanation of the negative temperature coefficient of action of topically-applied DDT. These authors obtained a positive temperature coefficient with injected doses of DDT against larvae of *Aëdes aegypti* (L.) and a negative temperature coefficient only with larvae exposed to low concentrations of DDT suspensions. Fan *et al.* (1948), therefore, suggested that the negative temperature coefficient evidenced with suspensions of DDT was due to the greater DDT-concentrating action of the insect cuticle (by adsorption) at low temperatures. Insufficient parallel injection experiments have been reported for other insects to permit generalizations, but the hypothesis of Fan *et al.* (1948) does not explain the negative temperature coefficient obtained with terrestrial insects exposed to residues (Pradhan 1949) or treated directly with known amounts of DDT (Guthrie 1950). Woodruff (1950), using injected doses of DDT against *Oncopeltus fasciatus* (Dall.), obtained a negative temperature coefficient over one temperature range and a positive temperature coefficient over a lower temperature range. The latter report confirms the interspecific differences among insects and emphasizes the difficulty in making generalizations applicable to all species.

Preliminary tests with female American roaches showed that both topical and injected doses of DDT gave negative temperature coefficients of action. This report presents the results of a study designed to correlate the effects of temperature on the factors of penetration and detoxification of topical doses of DDT and the detoxification of injected doses of DDT with the type and magnitude of the temperature coefficient of action with the two methods of administration.

METHODS.—*Topical Doses.*—An approximation of the LD-50 at 15° C. and 35° C. was obtained for topical doses of DDT. Female American cockroaches were held at room temperature (23 to 28° C.) prior to treatment. Topical applications of dioxane-DDT solutions of various known concentrations were made with a calibrated, micrometer-operated 0.25 cc. tuberculin syringe fitted with a 27-gauge needle which was bent downward near the tip. One mm.^{3} of the DDT solution was applied to the sternum of the roach between the prothoracic and mesothoracic coxae. This area of the roach was selected as the site of DDT application because poisoning symptoms appeared faster at lower dosages than when applications were made on the more sclerotized segments of the abdomen. Groups of 20 roaches each were treated with various dosages of DDT, placed at 35° C. or 15° C., and the percentage mortality determined at the end of 5 days.

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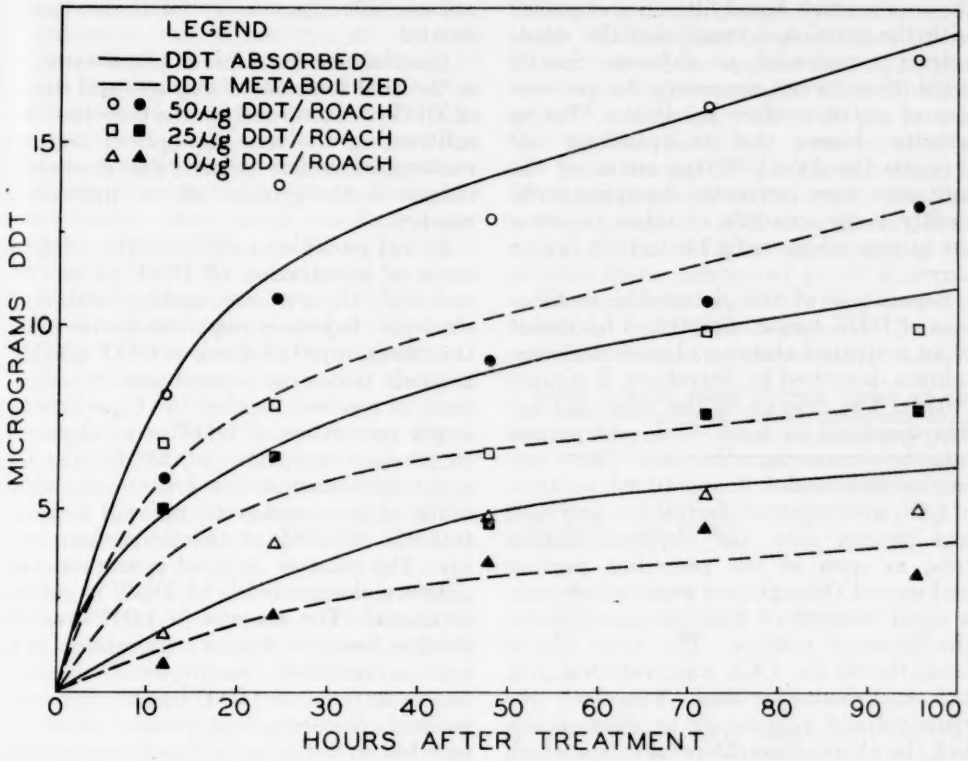

FIG. 1

Studies were made on the rates of penetration and detoxification of DDT at 15° C. and 35° C. Ten female American roaches each were treated, as previously described, with a given dose of DDT for each of five time intervals at each of the two temperatures. One 10-roach group at each dosage level at each of the two temperatures was observed for poisoning symptoms and 5 roaches of each group were sacrificed for the analysis of DDT and its degradation products, at various intervals after treatment.

Analyses of ether extracts of the roaches used in this experiment were made by the method of Schechter *et al.* (1945) as modified by Sternburg *et al.* (1950). A Beckman Model DU quartz spectrophotometer was used for the measurement of colors developed with 1.1 cc. benzene and 2.2 cc. sodium methoxide. Extraction of DDT and detectable metabolites from roaches was accomplished in a manner differing from that of Sternburg *et al.* (1950) only in the method of tissue maceration and the amounts of ether employed for extraction. Five treated roaches were anesthetized with CO_2 and placed in a 125 ml. Erlenmeyer flask and then rinsed free of external DDT by shaking for 15 seconds with 3 successive 25 ml. portions of ether. The three washes were pooled and evaporated and the residue analyzed for DDT content in the usual manner without further treatment prior to nitration. The rinsed roaches were placed in a Waring blendor to which was added first 200 cc. ether and then 10 grams anhydrous sodium sulphate. The mixture was then stirred for 30 seconds. The supernatant ether was then poured off, filtered through No. 1 Whatman filter paper, and the filtrate collected in a 300 ml. Erlenmeyer flask and evaporated to dryness over a steam bath. One hundred and fifty ml. of ether was added to the sodium sulphate roach tissue mixture in the Waring blendor and stirred for 10 seconds, the supernatant liquid poured off, filtered, and added to the residue in the 300 ml. Erlenmeyer flask. Then a final 50 ml. portion of ether was added to the Waring blendor and stirred with a stirring rod for 1 minute,

the supernatant liquid filtered and pooled with the previous extract and the whole extract evaporated to dryness. Special precautions were necessary to prevent loss of extract when using the Waring blendor. Losses due to splashing out through the loosely-fitting cover of the container were prevented by using sufficiently large amounts of ether to cover the stirrer when using the motor driven stirrer.

Separation of the detectable metabolites of DDT was accomplished by means of an activated alumina chromatographic column described by Sternburg & Kearns (1952). The residue of the ether extract was dissolved in 5 ml. CCl_4 and poured into the chromatographic tube. Three successive washes of 5, 5, and 10 ml. volumes of CCl_4 were made of the residue, and each was poured into the chromatographic tube as soon as the preceding portion had passed through to a point where only a small amount of fluid remained above the alumina column. The total eluate from the 25 cc. CCl_4 was collected in a 125 cc. Erlenmeyer flask. This flask was removed and another set in place to collect the eluate from 25 cc. acetone which was then passed through the column. The two solutions were then placed on a steam bath, evaporated to dryness, and the residues subsequently treated in the manner required to complete the Schechter-Haller analysis. The quantities of CCl_4 and acetone and their order of addition as employed in this procedure served to separate the metabolites of DDT responding to the Schechter-Haller test and permit the analysis of the known metabolites without interference from metabolites of unknown structures which respond to the test. The CCl_4 eluate contained DDT and DDE while the acetone eluate contained a metabolite which responded to the Schechter-Haller test in a manner similar to that of DDE in that it, too, formed a red-colored complex with sodium methoxide after nitration. Therefore, prior to analysis it was necessary to separate DDE from the unknown metabolite, hereafter referred to as Metabolite X. The amounts of DDT and DDE extracted and analyzed in mixture from roach tissues were easily calculated by an adaptation of the formula of Barnard & MacMichael (1930). Sternburg & Kearns (1952) have accomplished the separation of DDT and DDE, but this procedure was not considered necessary for these experiments.

Interference from insect tissue-extracts in the final solutions of extracts and rinses of DDT-treated roaches was corrected by subtracting the average optical density readings of similar extracts and rinses obtained from groups of 5 untreated roaches.

It was possible to estimate the relative rates of penetration of DDT at 15° C. and 35° C. without making chemical analyses. Injection experiments revealed that small injected doses of DDT quickly elicited poisoning symptoms (prostration) in roaches kept at 15° C., whereas, larger quantities of DDT were required to produce symptoms at 35° C. Taking into consideration the greater susceptibility of the roaches to internal concentrations of DDT at the lower temperature, the relative rates of penetration of different dosage levels of DDT could be estimated. The transfer of DDT-treated roaches from the higher temperature to a low temperature, where small internal concentrations of DDT quickly produce marked poisoning symptoms, made it possible to obtain symptomatic reactions in these roaches to the DDT which may have penetrated to a locus of DDT action but the effect of which was masked or prevented while the roaches were kept at the higher temperature. Prostration of the roaches at 15° C. was the symptomatic criterion used to determine when a significant amount of DDT had penetrated to a site of action. The earlier phases of DDT poisoning were more or less telescoped at low temperatures; therefore, the prostrate stage was considered the most reliable reaction stage for observational purposes.

Approximations of the LD-50 values at 15° C. and 35° C. were obtained for injected doses of DDT. Injections of dioxane-DDT solutions of known concentrations were made using a calibrated 0.25 ml. tuberculin syringe fitted with a straight 27-gauge needle. The needle tip was inserted beneath the cuticle into the lateral margin of the mesocoxacoria, and 1 $mm.^3$ of DDT solution of known concentration was ejected into the roach by means of a micrometer. Observations of the number of prostrate roaches at each dosage level were recorded at the end of 6 hours. Trial tests had shown that longer post-treatment intervals for ob-

servation did not change the results. Prostration was considered as the criterion of death although twitching of body appendages continued for some time after onset of prostration; at either temperature, death resulted in less than 5 days. Prostration at either temperature consistently resulted in death (complete immobility) but death resulted more quickly at 35° C. than at 15° C. It should be noted that in the presence of temperature fluctuations more variability in results should be expected and a longer observation interval would be necessary.

The metabolism of injected doses of DDT was studied at various dosage levels for roaches held at the two different temperature levels. Injected roaches were observed for poisoning symptoms, and, at appropriate times, groups of ten were selected and analyzed for DDT in the manner previously described. In the course of this study, it was observed that, within certain dosage-time limitations, it was possible to reverse the effects of DDT poisoning symptoms. That is, roaches prostrate from DDT poisoning at 15° C. could be revived to a state of normalcy by transfer to 35° C. and *vice versa*. The dosage-time-temperature relationship involved in the reversibility of poisoning symptoms was studied; roaches injected with various dosages of DDT were kept at each of the two temperatures for various time intervals, transferred to the opposite temperature and observed for a 90-minute period, then analyzed for DDT in the manner previously described. Thus, the rate of metabolism of DDT as affected by the various factors of dosage level, stage of poisoning and temperature was studied in relation to the phenomenon of reversibility of poisoning symptoms.

RESULTS.—The 5-day LD-50 for topical dosages of DDT is indicated by the data in table 1 to be 5–10 μg. per roach at 15° C. or 75 to 100 μg. per roach at 35° C. Data on the penetration and detoxification of various dosages of DDT at 15° C. and 35° C. are presented in figures 1 and 2 and tables 2 and 3. At comparable dosage levels, the amounts which penetrated after various time intervals are significantly higher at 35° C. than at 15° C. Penetration of DDT was 2 to 2.5 times as rapid at the higher temperature. The initial rates of penetration were more rapid at both temperatures at all dosage levels. The amounts that penetrated after 24 hours were progressively smaller in all cases. Calculations showed that 85 to 95 per cent of the applied dose at all dosage levels had penetrated after 96 hours at 35° C. while only 34 to 50 per cent of the applied doses had penetrated after the same time at 15° C. There seemed to be no appreciable difference in the percentage penetration of the different doses at 35° C., but a higher percentage of the smaller doses penetrated at 15° C.

The amounts of DDT which were metabolized to DDE, Metabolite X, and metabolites not responsive to the Schechter-Haller test were dependent on the amounts of DDT which had penetrated at the various dosage levels. At equivalent dosage levels, roaches kept at 35° C. absorbed more DDT and metabolized more than those kept at 15° C., but the percentages of the absorbed doses which were metabolized were not strikingly different at the two temperatures. At a given dosage level, temperature had little effect in changing the proportion of absorbed DDT which was metabolized. Table 4 presents calculations showing the ratio of absorbed DDT to metabolized DDT at three time intervals at the two temperatures for the various dosage levels. Where analyses were made with equivalent topical doses at both 15° and 35° C., the ratios of absorbed DDT to metabolized DDT were essentially equal after 24 and 96 hours but were slightly higher at 35° C. at 12 hours. In terms of absolute amounts, as shown in table 6, roaches kept at the higher temperature were found to contain from 2 to 6.8 times as much unchanged DDT as similarly treated roaches kept at 15° C.

The results of observational studies on the rates of penetration of DDT at 15° C. and 35° C. are presented in table 7. Roaches kept continuously at 15° C. and 35° C. showed no DDT symptoms during

Table 1.—The effect of temperature on the per cent mortality of female American cockroaches 5 days after topical treatment with DDT.

No. Roaches	Dose (μg. DDT)	Per Cent Mortality	
		15° C.	35° C.
20	5	10	—
20	10	80	—
20	15	100	—
20	50	—	20
20	75	—	40
20	100	—	90

Table 2.—The metabolism of DDT absorbed from topical applications to groups of 5 female American roaches held at 15° C.; all data are presented on a per roach basis.

Treatment		DDT Absorbed		Absorbed DDT Metabolized						Absorbed DDT Remaining Unchanged	
				to DDE		to Unknown		Total			
DDT Dose (μg.)	Hrs. After Treatment	μg.	% of Applied Dose	μg.	%	μg.	%	μg.	%	μg.	%
10	12	1.5	15.0	0	0	0.7	47.0	0.7	47.0	0.8	53.0
10	24	3.0	30.0	trace	trace	2.1	70.0	2.1	70.0	0.9	30.0
10	48	4.8	48.0	trace	trace	3.4	70.8	3.4	70.8	1.4	29.2
10	72	5.5	55.0	0	0	4.6	83.6	4.6	83.6	0.9	16.4
10	96	5.0	50.0	trace	trace	3.2	64.0	3.2	64.0	1.8	36.0
25	12	6.8	27.2	0	0	5.0	73.5	5.0	73.5	1.8	26.5
25	24	7.7	30.8	0	0	6.4	83.1	6.4	83.1	1.3	16.9
25	48	6.3	25.2	trace	trace	4.9	74.6	4.7	74.6	1.6	25.4
25	72	9.9	39.6	0.4	4.0	7.2	72.8	7.6	76.8	2.3	23.2
25	96	9.9	39.6	trace	trace	7.1	71.7	7.1	71.7	2.8	28.3
50	12	8.0	16.0	0	0	5.8	72.5	5.8	72.5	2.2	27.5
50	24	13.9	27.8	0	0	10.4	74.8	10.4	74.8	3.5	26.2
50	48	12.8	25.6	0	0	8.9	69.5	8.9	69.5	3.9	30.5
50	72	15.6	31.2	0.4	2.5	10.3	66.1	10.7	68.6	4.9	33.9
50	96	16.9	33.8	0.7	4.1	12.6	74.6	13.3	78.7	3.6	25.4

the 22 hours of the test. More than 50 per cent of the roaches treated with the two higher dosage levels and kept initially at 35° C. for 17 or 20 hours became prostrate within an hour after transfer to 15° C. Of the roaches treated with 75 μg. DDT and kept initially at 35° C. for 20 hours, 100 per cent became prostrate within 2 hours after transfer to 15° C. Lower dosages of DDT caused lower percentage prostration in roaches transferred from 35° C. to 15° C.

The two main points evidenced by the results of the observational study are: (1) Penetration of topically-applied DDT to a site of action within the roach is significantly faster at 35° C. than at 15° C. (2) The toxic effects of the larger quantities of DDT which penetrated at the higher temperature were not manifested at the high temperature but quickly became evident upon transfer to the low temperature.

These results left much to be desired in explaining the negative temperature coefficient of DDT action when topically applied to the female roach. The rate of penetration and the rate of metabolism of DDT as opposing factors in the toxic action of DDT were both affected by temperature increases. Since the rate of penetration was increased proportionately more than the rate of metabolism of DDT, no basis was provided for the hypothesis that topical doses of DDT are more effective at low temperatures due to a decrease in rate of detoxification of DDT. The evidence from both analytical and observational studies indicated that factors other than penetration and detoxification or elimination of DDT were necessary to explain the effect of temperature on the action of DDT.

The LD-50 value for injected DDT was found to be 2 to 3 μg. at 15° C. and 20 to 25 μg. at 35° C. (Table 8). Therefore, the negative temperature coefficient obtained with injected doses of DDT is of approximately the same magnitude as that obtained with topical applications. Injected DDT was 7 to 13 times as effective at 15° C. as at 35° C. while topical doses were approximately 7.5 to 20 times more effective at 15° C. than at 35° C. Exact determinations of LD-50 values were not made with either injected or topical doses of DDT, but the approximations at the different temperatures show negative temperature coefficients of action of almost equivalent magnitude with both methods of administration of DDT.

The metabolism of 20 μg. dosages of DDT, as shown in table 9 and figure 3, proceeded fairly rapidly in roaches kept continuously at 35° C. but was much slower in roaches kept continuously at 15° C. The initial rates of metabolism (up to 6 hours after injection) do not appear very different at the two temperatures, but metabolism after 6 hours was practically negligible at 15° C. Metabolism continued at a fairly steady rate up to 30 hours at 35° C. and continued at a progressively slower rate up to 77 hours

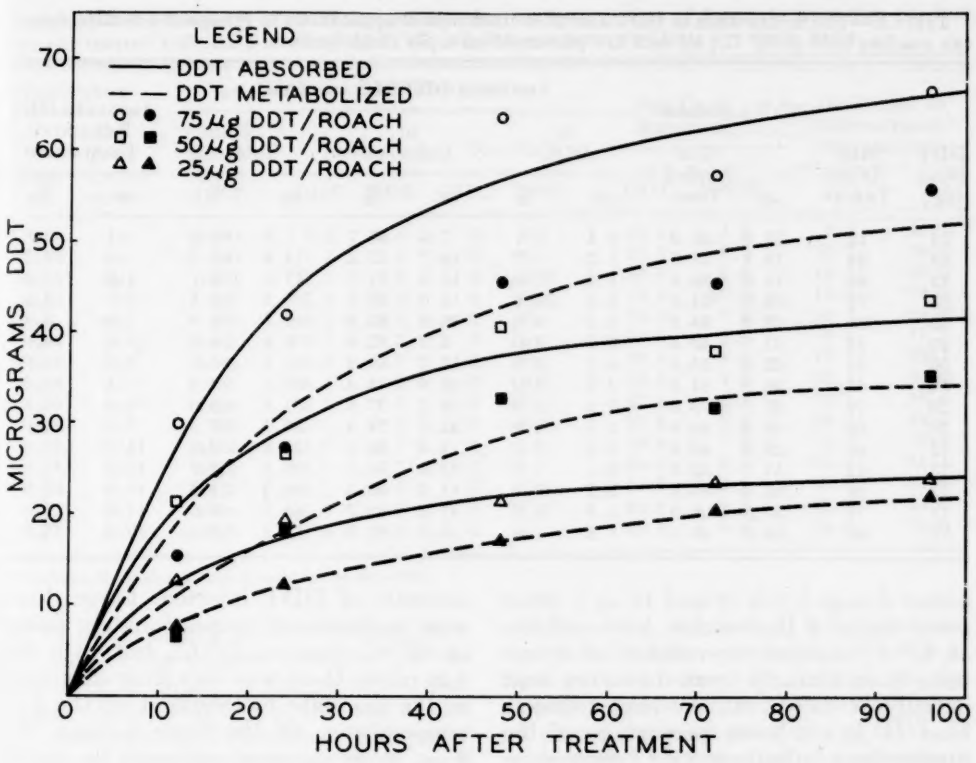

FIG. 2

after treatment when the last analysis was made. Poisoning symptoms were not evident in the roaches kept at 35° C. after an initial 1-hour period of locomotor instability; an equal volume of dioxane alone caused a slight irritability which disappeared in about 15 minutes. The DDT-treated roaches kept at 15° C. became prostrate in about 1 hour and never recovered. Analyses of roaches kept at 15° C. were not made after 48 hours because death occurred between 48 and 60 hours. While larger amounts of DDT were metabolized by roaches kept at 35° C., it must be kept in mind that the roaches at 15° C. were prostrate and in the process of dying within 1 hour after treatment.

Results with topical applications of DDT showed that roaches kept at 15° C. were capable of metabolizing larger amounts of DDT than were metabolized by the DDT-injected roaches used in this experiment. However, in the case of topical treatment, the internal tissues were subjected to DDT by the gradual process of cuticular penetration; whereas, in the case of the injected roaches, the internal tissues received instantaneous exposure to 10 fold the LD-50 dose at 15° C. Therefore, the magnitude of the differences in amounts of DDT metabolized at 15° C. and 35° C. obtained with injected doses of 20 μg. DDT is not just a measure of the temperature effect on DDT-metabolism but includes the factor of temperature effect on the intrinsic toxic action of DDT. This interpretation is brought out more clearly when smaller injected doses of DDT are administered.

The metabolism of DDT in correlation with the effect of an increase in temperature on the reversibility of DDT poisoning symptoms is presented in figure 4 and table 10. The percentage of roaches showing reversibility at one dosage level decreased with an increase in time at either temperature prior to transfer to the opposite temperature. The percentage of roaches exhibiting reversibility after being kept initially at 15° C. decreased more rapidly at the higher dosage levels. Conversely, the decrease in the percentage of roaches showing reversibility after being kept initially at 35° C. was more rapid at the lower dosage levels. With the two

Table 3.—The metabolism of DDT absorbed from topical applications to groups of 5 female American roaches held at 35° C.; all data are presented on a per roach basis.

DDT Dose (μg.)	Hrs After Treat-	DDT Absorbed		Absorbed DDT Metabolized						Absorbed DDT Remaining Unchanged	
				to DDE		to Unknown		Total			
		μg.	% of Applied Dose	μg.	%	μg.	%	μg.	%	μg.	%
25	12	13.0	52.0	0.4	3.1	7.5	57.7	7.9	60.8	5.1	60.8
25	24	19.4	77.6	1.5	7.7	10.7	55.2	12.2	62.9	7.2	37.1
25	48	21.6	86.4	1.5	7.0	15.5	71.7	17.0	78.7	4.6	21.3
25	72	23.7	94.8	2.5	10.6	18.0	75.9	20.5	86.5	3.2	13.5
25	96	23.9	95.6	2.2	9.2	20.2	84.6	22.4	93.8	1.5	6.2
50	12	21.7	43.4	0.7	3.0	5.9	27.0	6.6	30.0	15.1	70.0
50	24	27.6	55.2	0.7	2.5	17.7	64.2	18.4	66.7	9.2	35.8
50	48	40.8	81.6	2.0	5.0	30.4	74.4	32.4	79.4	8.4	25.6
50	72	37.7	75.4	2.2	5.8	29.1	77.2	31.3	83.0	6.4	22.8
50	96	42.5	85.0	2.5	5.9	32.9	77.4	35.4	83.3	7.1	22.6
75	12	29.9	40.0	0.7	2.3	14.5	48.5	15.2	50.8	14.7	51.5
75	24	41.6	55.4	0.7	1.7	25.8	62.0	26.5	63.7	15.1	38.0
75	48	63.0	84.0	3.3	5.2	41.6	66.1	44.9	71.3	18.1	33.9
75	72	57.0	76.0	1.3	2.3	47.7	83.7	45.0	86.0	12.0	16.3
75	96	66.0	88.0	1.2	1.8	54.0	81.8	55.2	83.6	10.8	18.2

higher dosage levels (8 and 12 μg.), lower percentages of the roaches kept initially at 15° C. showed reversibility of symptoms than similarly-treated roaches kept initially at 35° C. At the lowest dosage level (4 μg.) a lower percentage of the roaches kept initially at 35° C. showed reversibility.

The data obtained by chemical analysis of the roaches used for prostration-recovery studies, presented in figure 4, reveal that the magnitude of the difference in amounts of DDT metabolized at 15° C. and 35° C. was determined by the amounts of DDT injected. Large doses were metabolized proportionately faster at 35° C. than at 15° C., but with the 4 μg. dose, there was very little difference in the amounts metabolized at the two temperatures. Of the three dosages, the 8 μg. dose appeared optimum for maximum metabolism at both temperatures. Less than 50 per cent of the 12 μg. dose, about 50 per cent of the 4 μg. dose, and greater than 50 per cent of the 8 μg. dose were metabolized 12 hours after injection. Reference to table 8 shows that the relative amounts of unchanged DDT remain-

Table 4.—The recovery of DDT and its metabolites from groups of 5 female American roaches topically treated with DDT and kept at 15° C.; all data are presented on a per roach basis.

Treatment		μg. DDT and DDE Recovered					Per Cent Recovery		DDT Lost as Undetectable[1] Metabolites	
Dose μg.	Hrs. After Treat-ment	Flask & Roach Rinse DDT	Inside DDT	Inside DDE	Excreta DDT	Excreta DDE	as DDT	as DDE	(μg.)	%
10	12	8.5	0.8	0	0	0	93.0	0	0.7	7.0
10	24	7.0	0.9	trace	0	0	79.0	trace	2.1	21.0
10	48	5.2	1.4	trace	0	0	66.0	trace	3.4	34.0
10	72	4.5	0.9	0	0	0	54.0	0	4.6	46.0
10	96	5.0	1.8	trace	0	0	68.0	trace	3.2	32.0
25	12	18.2	1.8	0	0	0	80.0	0	5.2	20.2
25	24	17.3	1.3	0	0	0	74.4	0	6.4	25.6
25	48	18.7	1.6	trace	0	0	80.4	trace	4.9	19.6
25	72	15.1	2.3	0.4	0	0	69.6	1.6	7.2	28.8
25	96	15.1	2.8	trace	0	0	71.6	trace	7.1	28.4
50	12	42.0	2.2	0	0	0	88.4	0	5.8	11.6
50	24	36.1	3.5	0	0	0	79.2	0	10.4	20.8
50	48	37.2	3.9	0	0	0	82.2	0	8.9	17.8
50	72	34.4	4.9	0.4	0	0	78.6	0.8	10.3	20.6
50	96	33.1	3.6	0.7	0	0	73.4	1.4	12.6	25.2

[1] Includes Metabolite X since it could not be measured.

Table 5.—The recovery of DDT and its metabolites from groups of 5 female American roaches topically treated with DDT and kept at 35° C.; all data are presented on a per roach basis.

Treatment		μg. DDT and DDE Recovered					Per Cent Recovery		DDT Lost as Undetectable* Metabolites	
Dose μg.	Hrs. After Treatment	Flask & Roach Rinse DDT	Inside		Excreta		as DDT	as DDE	(μg.)	%
			DDT	DDE	DDT	DDE				
25	12	12.0	5.1	0.4	0	0	68.4	1.6	7.5	30.0
25	24	5.6	7.2	1.5	0	0	51.2	6.0	10.7	42.8
25	48	3.4	4.6	1.3	0	0.2	32.0	6.0	15.5	62.0
25	72	1.3	3.2	2.5	0	0	18.0	10.0	18.0	72.0
25	96	1.1	1.5	2.2	0	0	10.4	8.8	20.2	80.8
50	12	28.3	15.1	0.7	0	0	86.8	1.4	5.9	11.8
50	24	22.4	9.2	0.7	0	0	63.2	1.4	17.7	35.4
50	48	9.2	8.4	1.8	0	0.2	35.2	4.0	30.4	60.8
50	72	12.3	6.4	2.1	0	0.1	37.4	4.4	29.1	56.2
50	96	7.5	7.1	2.2	0	0.3	29.2	5.0	32.9	65.8
75	12	45.1	14.7	0.7	0	0	79.6	1.0	14.5	19.4
75	24	33.4	15.1	0.7	0	0	64.8	0.8	25.8	34.4
75	48	12.0	18.1	3.0	0	0.3	40.0	4.4	41.6	35.8
75	72	18.0	8.0	1.1	0	0.2	34.6	1.8	47.7	63.6
75	96	9.0	10.8	0.9	0	0	26.4	1.6	54.0	72.0

* Includes Metabolite X since it could not be measured.

ing 12 hours after injection deviate from the ratio of the original dosages. The direction of deviation is the same but the magnitude of deviation is different at the two temperatures. From the original ratio of 3:2:1 (corresponding to 12, 8, and 4 μg. DDT), the ratios after 12 hours at 35° and 15° C. have become 3.5:1.2:1.0 and 4.8:1.7:1.0, respectively. Using the ratio existing after 12 hours at 35° C. (3.5:1.2:1.0) as a basis, it seemed reasonable to make the tentative interpretation that the initial rate of the process of DDT metabolism is dependent on two factors: namely, DDT concentration and what will be called, for lack of a better term, the detoxification potential. Detoxification potential may be defined as the maximal sum of factors present that interact in metabolizing quantities of DDT. It is measured in terms of the maximum quantity of DDT capable of being metabolized during the initial 12 hours after injection. This value is only slightly greater at 35° than at 15° C. when an optimum concentration of DDT is injected. At 35° C. the potential cannot be raised by using higher concentrations of DDT up to and including the LD-50 dose at 35° C., but would theoretically be lowered

Table 6.—The effect of temperature on the ratio of the amounts of absorbed DDT to the amounts of metabolized DDT and on the relative amounts of unchanged DDT remaining in female American cockroaches at various times after treatment with topical applications of DDT. Groups of 5 treated roaches were used in each analysis, but the data are presented on a per roach basis.

Treatment		μg. DDT Absorbed		μg. DDT Metabolized		μg. Absorbed DDT Unchanged		Ratio of Amt. Absorbed to Amt. Metabolized		Ratio of Unchanged DDT at 35° C. to DDT at 15° C.
Dose μg. DDT	Hrs. After Treatment	15° C.	35° C.	15° C.	35° C.	15° C.	35° C.	15° C.	35° C.	
10	12	1.5	—	0.7	—	0.8	—	2.14	—	—
10	24	3.0	—	2.1	—	0.9	—	1.43	—	—
10	96	5.0	—	3.2	—	1.8	—	1.56	—	—
25	12	6.8	13.0	5.0	7.9	1.8	5.1	1.36	1.65	2.83
25	24	7.7	19.4	6.4	12.2	1.3	7.2	1.20	1.59	5.50
25	96	9.9	23.9	7.1	22.4	2.8	9.5	1.40	1.07	3.40
50	12	8.0	21.7	5.8	6.6	2.2	15.1	1.38	3.29	6.86
50	24	13.9	27.6	10.4	18.4	3.5	9.2	1.34	1.50	2.63
50	96	16.9	42.5	13.3	35.4	3.6	7.1	1.27	1.20	2.00
75	12	—	29.9	—	15.2	—	14.7	—	1.99	—
75	24	—	41.6	—	26.5	—	15.1	—	1.60	—
75	96	—	66.0	—	55.2	—	10.8	—	1.20	—

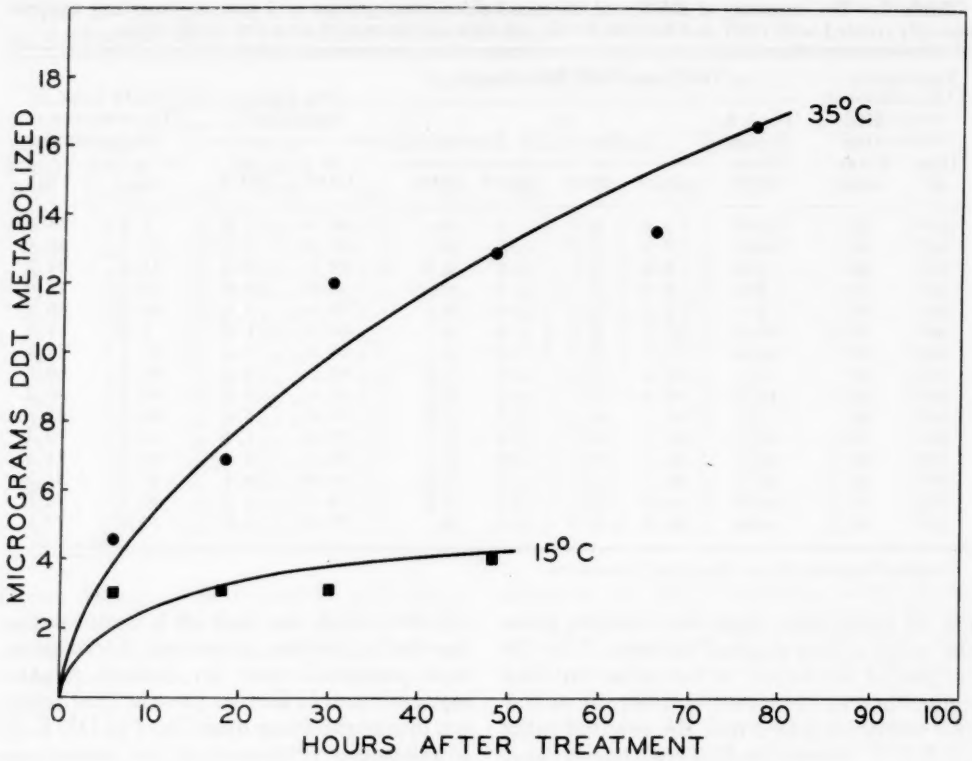

FIG. 3

at still higher concentrations. At 15° C., lowering of the potential occurs with lower concentrations of DDT than at 35° because of the increased speed of action of such concentrations in disrupting normal function of many processes, including the unknown factors affecting the detoxification potential. Evidence for this interpretation is shown by the fact that in terms of absolute amounts of DDT metabolized in 12 hours at 35° C., there was no appreciable difference between the 8 and 12 μg. dosages; and a similar amount was metabolized at the 20 μg. dosage used in the preceding experiment (Figure 3). Since the amounts of 4 μg. doses metabolized at 15° and 35° C. were almost equal, the ratio (4.5:1.7:1.0) for the amounts of unchanged DDT after 12 hours at 15° C. indicated that the low temperature had only slightly decreased the potential for detoxifying relatively low doses of DDT but had drastically reduced the potential for detoxifying high doses of DDT.

A correlation of the data on reversibility of symptoms with the analytical data on metabolism shows that the slight increase in rate of metabolism of low doses of DDT (but larger than LD-50 dose at 15° C.) with increase in temperature is of insufficient magnitude to explain the large initial (0 to 12 hours) difference in reaction of roaches kept at 15° and 35° C. The maximum initial rate of metabolism at 15° C. is only slightly less than that at 35° C. when the optimum concentration of DDT is injected. At high dosage levels (above 8 μg. DDT), the rate of metabolism is limited mostly by the potential for detoxifying DDT rather than by the concentration of injected DDT. The dosage optimum obtained for maximum metabolism at either temperature was paralleled by evidence of a dosage optimum for the least difference in the percentages of roaches showing reversibility of symptoms after being kept at 15° or 35° C. for various periods previous to being transferred to the opposite temperature.

Degradation Products of DDT.—Two metabolites of DDT responsive to the Schechter-Haller (1945) test were separated by use of the chromatographic technique of Sternburg & Kearns (1952).

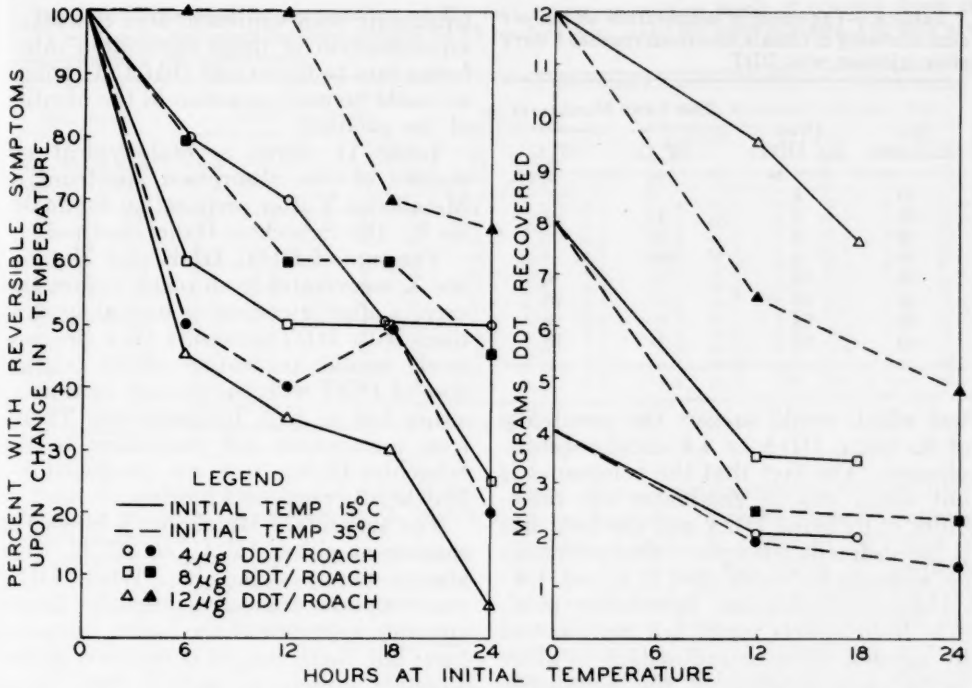

FIG. 4

One of the metabolites of DDT, referred to throughout this paper as DDE was tentatively identified as such from inconclusive evidence. The product has the same absorption spectrum as DDE treated in accordance with the Schechter-Haller procedure when corrections are made for interfering materials which accompany the extraction of the product from roaches. Samples of this product of roach metabolism of DDT, when subjected to treatment with refluxing ethylene glycol-KOH solution, result in its complete conversion to an alkali soluble product which when subjected to the the Schechter-Haller test corresponds to DDA (p,p'dichlorodiphenyl acetic acid).

The identity of the other metabolite mentioned, Metabolite X, is still in doubt. It was eluted from a column of activated alumina by acetone or ethyl ether and was not eluted by petroleum ether, carbon tetrachloride, or benzene which fact indicates that it is not DDE. The compound has an absorption peak of 450 mμ when subjected to the Schechter-Haller

Table 7.—The effect of temperature on the rate of penetration of topically-applied DDT as determined by observation of poisoning symptoms.

Treatment			No. of Roaches Prostrate at Various Intervals After Treatment					
No. Roaches	Dose (μg. DDT)	Conditions after treatment with DDT	17 Hrs.	18 Hrs.	19 Hrs.	20 Hrs.	21 Hrs.	22 Hrs.
10	15	Roaches kept at 35° C. for	1	4*	4	—	—	—
10	50	17 hrs. then placed at 15° C.	0	5*	6	—	—	—
10	75	& observed for 2 hrs.	2	6*	6	—	—	—
10	15	Kept at 35° C. for 20 hrs.	—	—	—	0	2*	2
10	50	then placed at 15° C. and	—	—	—	0	6*	6
10	75	observed for 2 hrs.	—	—	—	0	8*	10
10	15	Kept continuously at 15° C.	1	1	1	1	1	1
10	50		0	0	0	0	0	0
10	75		1	1	1	1	2	2

* One hour after transfer from 35° C. to 15° C.

Table 8.—The effect of temperature on the per cent mortality of female American roaches 5 days after injection with DDT.

No. Roaches	Dose (μg. DDT)	Per Cent Mortality	
		15° C.	35° C.
20	1	0	—
20	2	45	—
20	3	75	—
20	4	100	—
20	15	—	0
20	20	—	20
20	25	—	70
20	30	—	95

test which would suggest the possibility of its being DDA or 4,4′-dichlorobenzophenone. The fact that the compound is not alkali soluble eliminates the possibility of its being DDA and the fact that it has different adsorption characteristics on alumina indicates that it is not 4,4′-dichlorobenzophenone. Interfering products from insects could not be removed by saponification or sulfonation to allow partial identification of the metabolite by its ultraviolet absorption spectrum.

Metabolite X was found to be stable to the action of a 2-hour period of refluxing with KOH-saturated ethyl alcohol and to treatment with concentrated H_2SO_4 for at least 1 hour over a steam bath. Extraction of the refluxed mixture with ether after dilution with water gave what looks like complete recovery of the metabolite as determined by the Schechter-Haller method of analysis. Metabolite X is soluble in concentrated H_2SO_4, but when diluted strongly with water it would appear that it may be quantitatively recovered by extraction with ether. Neither treatment with sulphuric acid nor alkali saponification of lipids eliminated interfering fats to the extent that U.V. analysis could be used as a clue to the identity of the product.

Table 11 shows several typical examples of the absorption spectrum of Metabolite X after preparation for analysis by the Schechter-Haller method.

The sum of DDT, DDE, and Metabolite X recoverable from roach tissues and excreta after injections or topical applications with DDT amounts to a progressively smaller percentage of the original dose of DDT with the passage of time at either low or high temperatures. Therefore, metabolites not responsive to the Schechter-Haller test are produced by female American cockroaches.

The amounts of Metabolite X formed in roaches at either 15° C. or 35° C. were always barely detectable. When DDT was applied topically, slightly larger amounts appeared at the higher temperature, but there was no correlation in the amounts present at various time intervals after 12 hours. It appears that the amount of Metabolite X increases to a low maximum shortly after treatment of the roaches with DDT and does not radically deviate from that maximum. Since the identity of the metabolite remains unsolved, and due to the fact that only small amounts were found, Metabolite X was considered as an undetectable metabolite in all calculations.

As shown in Tables 2 to 6, inclusive, the amounts of DDE found at various times following injection or topical applications of DDT show little correlation

Table 9.—The metabolism of an injected dose of 20 μg. DDT per female American roach kept at 15° C. or 35° C. after treatment. Groups of 10 roaches were used for each analysis, but data are presented on a per roach basis.

Treatment			Microgram of DDT and DDE Recovered*			Micrograms of DDT Metabolized			Total Recovery of Applied Dose					
				Inside					As DDT		As DDE		Total	
Dose (μg.)	Temp. ° C.	Hrs. After Treat.	Rinse DDT	DDT	DDE	To DDE	To Unknown	Total	μg.	%	μg.	%	μg.	%
20	—	0	2.0	19.0	0	—	—	—	21.0	99.5	0	0	19.9	99.5
20	—	0	0.7	18.1	0	—	—	—	18.8		0	0		
20	15	6	0.8	16.1	0.9	0.9	2.2	3.1	16.9	84.5	0.9	4.5	17.8	89
20	35	6	1.0	14.3	1.6	1.6	3.1	4.7	15.3	76.5	1.6	8.0	16.9	84
20	15	18	1.9	15.2	1.3	1.3	1.9	3.2	17.1	85.5	1.3	6 5	18.4	92
20	35	18	0.8	12.4	2.2	2.2	4.6	6.8	13.2	66.0	2.2	11.0	15.4	77
20	15	30	1.2	15.5	2.3	2 3	1.0	3.3	16.7	83.5	2.3	11.5	19.0	95
20	35	30	0.8	7.2	2.8	2.8	9.2	12.0	8.0	40.0	2.8	14.0	10.9	54
20	15	48	0.9	15.1	2.0	2.0	2.0	4.0	16.0	80.0	2.0	10.0	18.0	90
20	35	48	0.7	6.5	2.9	2.9	9.9	12.8	7.2	36.0	2.9	14.5	10.1	50
20	35	66	trace	6.5	2.7	2.7	10.8	13.5	6.5	32.5	2.7	13.5	9.2	46
20	35	77	0	3.3	2.3	2.3	14.4	16.7	3.3	16.5	2.3	11.5	5.6	28

* DDE expressed as molecular equivalents of DDT.

Table 10.—The effect of temperature on the metabolism on various levels of injected doses of DDT by female American roaches. Groups of 10 roaches were used for each analysis, but data are presented on a per roach basis.

Treatment			Micrograms of DDT and DDE* Recovered					Micrograms of DDT Metabolized			Total Recovery of Applied Dose					
				Inside		Excreta					As DDT		As DDE		Total	
Dose (μg.)	Temp. ° C.	Hrs. After Treat.	Rinse DDT	DDT	DDE	DDT	DDE	To DDE	To Unknown	Total	μg.	%	μg.	%	μg.	%
4	15	12	0.2	1.8	0.3	0	0	0.3	1.7	2.0	2.0	30.0	0.3	7.5	2.3	57.5
4	15	18	0.1	1.8	0.4	0	0	0 4	1.7	2.1	1.9	47.5	0.4	10.0	2.3	57.5
4	35	12	0	1.9	0.3	0	0	0.3	1.8	2.1	1.9	47.5	0.3	7.5	2.2	55.0
4	35	24	trace	1.3	0.5	0	0	0.5	2.2	2.7	1.3	32.5	0.5	12.5	1.8	45.0
8	15	12	0.6	2.8	0.4	0	0	0.4	4.2	4.6	3.4	42.5	0.4	5.0	3.8	47.5
8	15	18	0.1	3.3	0.3	0	0	0.3	4.3	4.6	3.4	42.5	0.3	3.7	3.7	46.2
8	35	12	0.1	2.2	0.3	0	0	0.3	5.4	5.7	2.3	28.7	0.3	3.8	2.6	32.5
8	35	24	0.1	2.1	0.7	0	0	0.7	5.1	5.8	2.2	27.5	0.7	8.7	2.9	36.2
12	15	12	0.4	9.2	0.3	0	0	0.3	2.2	2.4	9.6	80.0	0.3	2.5	9.9	82.5
12	15	18	0.6	7.1	0.4	0	0	0.4	3.9	4.3	7.7	64.1	0.4	3.4	8.1	67.5
12	35	12	0.3	6.3	0.3	0	0	0.3	5 1	5.4	6.6	35.0	0.3	2.5	6.9	57.5
12	35	24	0 2	4.6	0.6	0	0	0.6	6.6	7.2	4.8	40.0	0.6	5.0	5.4	45.0

* All figures for DDE are expressed as molecular equivalents of DDT.

Table 11.—Typical examples of data for the absorption spectrum of Metabolite X in the Schechter analysis.

Example No.	Optical Density at Following Wavelengths (Wavelengths in Millimicrons)				
	520	530	540	550	560
1	.063	.075	.079	.069	.047
2	.063	.080	.093	.085	.069
3	.074	.092	.096	.091	.069
4	.025	.038	.041	.038	.022
5	.040	.043	.041	.039	.035

with time or the temperature at which the roaches were kept after treatment. Following topical applications of DDT, the amounts of DDE found were usually higher at 35° C. than at 15° C. but no difference was noticed in amounts found following injections of DDT. The amounts found in any case were insignificant in accounting for the metabolized portion of absorbed or injected DDT.

Apparently DDE and Metabolite X are intermediate products formed in the degradation of DDT, but tests to determine whether or not roaches metabolize injected or topically-applied DDE have not been made at the present time.

SUMMARY.—In the female American cockroach, both topical and injected doses of DDT show negative temperature coefficients of action at temperatures of 15° and 35° C. The 5-day LD-50 values are 5 to 10 μg. at 15° and 75 to 100 μg. at 35° for topically-applied DDT and 2 to 3 μg. at 15° and 20 to 25 μg. at 35° C. for injected DDT.

Chemical analyses correlated with the onset of poisoning symptoms from topical applications of DDT show that penetration of DDT is faster at 35° than at 15° C. However, the effect of temperature in changing the equilibrium between the opposing forces of penetration and detoxification of DDT does not account for the negative temperature coefficient of action of topical doses of DDT. The percentage metabolism of absorbed DDT is approximately equal at the two temperatures when equivalent dosages are compared. Consequently, in terms of absolute amounts, the unchanged DDT found in roaches kept at 35° is greater than that found in roaches kept at 15°; at the same time, the roaches kept at 35° appear normal while those at 15° are in the prostrate stage of poisoning. The larger amounts of unchanged DDT in normal-appearing roaches at 35° C. become effective by causing prostration of the roaches upon changing the temperature to 15° C.

Injected doses of DDT greater than the LD-50 dose at 15° C., but smaller than the LD-50 dose at 35° C., cause prostration, within one hour, of roaches kept at 15° C. but do not seriously affect roaches kept at 35° C. Transfer of treated roaches from one temperature to the other results in reversal of poisoning symptoms; roaches kept initially at 35° C. become prostrate upon transfer to 15° C., and roaches kept initially at 15° C. recover appearances of normalcy upon transfer to 35° C. If treated roaches are kept at 15° C. for excessive periods of time before transfer, reversal of symptoms can no longer be accomplished; the time

required before prostration becomes irreversible decreases with increasing dosages of DDT.

The rate of metabolism of DDT within the first 12 hours after injection is determined by two factors: namely, the amount of DDT injected and the detoxification potential of the roach. At 35° C. the detoxification potential is not raised or lowered with increasing doses of DDT (from 8 μg. to 20 μg.), but at 15° C. the detoxification potential is reduced by doses in excess of 8 μg. of DDT.

A correlation of the data on reversal of symptoms and the data on metabolism of DDT leads to the conclusion that the lower rate of metabolism of large doses of DDT at low temperatures is the result of the increased effectiveness of DDT in disrupting many physiological functions, which includes those processes responsible for the metabolism of DDT. The direct effect of temperature on the metabolism of injected DDT seems incidental to the intoxicating process. Thus, the negative temperature coefficient of action of DDT must be based on the effect of temperature on the intrinsic susceptibility of some physiological system to DDT.

The metabolites of DDT responding to the Schechter-Haller test formed a very small portion of the total metabolized portion of both topical and injected doses of DDT. At both 15° C. and 35° C., the amounts of DDE and a product termed Metabolite X, recoverable from treated roaches, reached a maximum shortly after treatment, while the amounts of undetectable metabolites increased with time after treatment. This indicates that both DDE and Metabolite X may be intermediates formed in the degradation of DDT. The identity of Metabolite X and its relationship to DDE and undetectable metabolites in the process of degradation of DDT remain undetermined. Also, it has not been established that Metabolite X or undetectable metabolites have any significant role in the action of DDT.

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Metabolic Fate of DDT when Applied to Certain Naturally Tolerant Insects[1]

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The ability of DDT-resistant strains of houseflies to detoxify DDT by dehydrochlorination with the formation of the ethylenic analogue DDE (2,2-bis-(*p*-chlorophenyl)-1,1-dichlorethylene) has been reported by several workers (Sternburg & Kearns 1950, Perry & Hoskins 1950). Winteringham *et al.* (1951) found that resistant houseflies were able to dehydrochlorinate 2,2-bis-(*p*-bromophenyl)-1,1,1-trichloroethane in a similar manner. Adult houseflies of nonresistant strains were found unable to degrade DDT in this manner by Sternburg & Kearns, while Perry & Hoskins report that normal stains produce DDE, but to a much lesser degree than resistant strains. Winteringham *et al.* found no dehydrochlorination of the dibromo analogue of DDT by nonresistant houseflies. Since resistance acquired by certain strains of houseflies to DDT appears to be due to the development of a mechanism whereby detoxification of this compound takes place with the formation of a nontoxic metabolite, it was felt that a study of the metabolism and absorption of DDT by various insects normally resistant to DDT might furnish additional information on the subject of resistance, and possibly on the mode of action of DDT. The insects investigated were the Mexican bean beetle, *Epilachna varivestis* Mulsant, the red-banded leaf roller, *Argyrotaenia velutinana* (Walker), the red-legged grasshopper, *Melanoplus femur-rubrum* (DeGeer), and the differential grasshopper, *M. differentialis* (Thomas). The natural resistance of these insects is such that control by DDT is not economically possible.

METHOD OF ANALYSIS.—The method of Schechter *et al.* (1945) for the determination of DDT and related compounds was used in this study. The chromatographic separation described by Sternburg & Kearns (1952) was used to establish the identity of the metabolite formed and to investigate the possibility of the formation of a metabolite other than DDE. Optical densities of the colored solutions produced by the Schechter method were determined with a Beckman DU quartz spectrophotometer, using cells with a 1 cm. light path. The colors were developed in 1.1 ml. benzene plus 2.2 ml. methanolic $NaOCH_3$(10.0 $\pm$0.1%). Results in all the tables in this report are expressed as recovery per insect in order to facilitate interpretation of the data, but it should be understood that in each case analysis was actually made of the extract of a group of insects, and the recovery divided by the total number of insects in the group. Thus, a figure of 0.1 μg. in a table was actually much greater for the group and within the range of accuracy of the method.

MEXICAN BEAN BEETLE.—*Topical application of DDT.*—Last instar larvae and pupae of the Mexican bean beetle were treated topically with 20 μg. DDT in 2 mm.^{3} ethanol, applied to the dorsum while under CO_2 anesthesia, and then kept at room temperature until sacrificed for analysis. Larvae and pupae treated topically with this dosage do not develop symptoms of DDT poisoning. Even when the dosage is increased to 50 μg. DDT per insect, no symptoms appear, and larvae so treated pupate and produce normal adults.

The degree of absorption and degradation of DDT by larvae and pupae is shown in table 1. Absorption of DDT by both larvae and pupae is slow; 24 hours after treatment 13.6 μg. of 20 μg. DDT can be recovered externally from larvae,

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Table 1.—Recovery of DDT and the metabolite DDE from Mexican bean beetle larvae and pupae treated topically with 20 μg. DDT per insect. Ten to twenty insects in each group, but results are given as recovery per insect.

TIME IN HOURS	STAGE	RECOVERED: External μg. DDT	RECOVERED: Internal μg. DDT	RECOVERED: Internal μg. DDE	MISSING μg. DDT	μg. DDT METABOLIZED
12	larva	17.2	0.1	0.6	2.0	2.7
24	larva	13.6	0.7	0.9	4.7	5.7
28	larva	13.1	1.0	1.2	4.6	5.9
12	pupa	18.2	0.7	0.4	0.7	1.1
24	pupa	16.8	0.7	0.6	1.8	2.5

Table 2.—Recovery of DDE from Mexican bean beetle larvae and pupae treated topically with 20 μg. DDE per insect. Three insects per group, but results expressed as recovery per insect.

Time in Hours	Stage	Recovered		μg. DDE Metabolized
		External μg. DDE	Internal μg. DDE	
4	larva	17.0	0.7	2.3
10	larva	10.7	1.3	8.0
27	larva	6.8	1.8	11.4
10	Pupa	14.8	1.5	3.7
27	pupa	8.1	2.7	9.2

while 16.8 μg. of 20 μg. DDT can be recovered externally from pupae.

DDT does not accumulate within the body of this insect in amounts equivalent to that absorbed. The greater part of the DDT absorbed is degraded, but only a fraction of this can be accounted for as the dehydrochlorinated product, DDE. Apparently the metabolism of DDT by this insect results in the ultimate formation of a compound or compounds that do not give a color by the Schechter method. It is possible that DDE is an intermediate in this process, since metabolism of DDE can be demonstrated in this insect. In table 2, the recovery of DDE, internally and externally at various intervals of time after topical application of 20 μg. DDE per insect, indicates that metabolism of DDE itself takes place continually, so that this compound does not tend to accumulate in large amounts within the body. DDA (bis(-*p*-chlorophenyl) acetic acid) is not produced by this insect, and, if applied topically to larvae and pupae, can be completely recovered 27 hours after application, about 20% of a 20 μg. dosage from within the body, the remaining 80% not being absorbed. Therefore DDA is not an intermediate in the formation of an unknown metabolite.

Metabolism of ingested DDT.—Groups of 10 to 20 bean beetle larvae were permitted to feed on sections of bean leaves that were coated with a known deposit of DDT. Only one surface of a leaf was treated, and this was placed against moist filter paper, so that the larvae could not make contact with the DDT, except by their mouth parts during feeding. The larvae used were about one half grown and had been deprived of food for 24 hours prior to the test in order to insure a good appetite. The time spent in feeding by each larva was not longer than 10 minutes, after which it was transferred to a clean flask and held for a definite period of time before being sacrificed for analysis. The tissues of 10 to 20 larvae were assayed together for each time interval. The amount of DDT eaten by each group was determined by analyzing the uneaten portion of the leaf and subtracting the DDT found from that originally present on the intact leaf.

Within 5 minutes after completion of feeding, larvae generally began to develop tremors. These gradually increased in intensity, reaching a maximum level

Table 3.—Recovery of DDT and the metabolite DDE from Mexican bean beetle larvae fed varying amounts of DDT. 10 to 20 insects per group; results expressed as recovery per insect.

Time After Feeding	Condition of Larvae	μg. DDT Eaten	Recovered		Per Cent Recovery	μg. DDT Missing	Per Cent DDT Missing	μg. DDT Metabolized	Per Cent DDT Metabolized
			μg. DDT	μg. DDE					
5 min.	tremors starting	2.20	1.42	0.80	104.9	—	—	0.78	35.0
15 min.	tremors	2.64	1.36	.65	78.8	0.56	21.2	1.28	48.5
30 min.	tremors	4.47	2.88	.62	79.8	0.90	20.2	1.59	35.3
1 hour	slight tremors	3.70	2.16	.53	74.3	0.95	25.7	1.54	41.6
2 hours	normal	2.82	1.27	.61	69.1	0.87	30.9	1.55	55.0
4 hours	normal	4.95	.89	.93	38.8	3.03	61.2	4.06	82.2
7 hours	normal	5.45	.64	1.10	34.1	3.59	65.9	4.81	88.2
10 hours	normal	2.50	.61	.58	50.1	1.25	44.9	1.89	75.8
13 hours	normal	3.40	.67	1.09	55.3	1.52	44.7	2.73	80.5
16 hours	normal	5.50	.27	1.27	30.5	3.82	69.5	5.23	95.4
28 hours	normal	30.00	.45	1.74	7.9	27.62	92.1	29.55	98.5
72 hours	normal	8.89	.27	1.84	26.0	6.58	74.0	8.62	97.0

Table 4.—Recovery of DDT and DDE from red-banded leaf roller larvae after topical application of 20 μg. DDT per larva. Results expressed as average recovery per larva; from four to eight larvae at each time interval.

Time in Hours	External μg. DDT	Internal μg. DDT	Internal μg. DDE	Excreta μg. DDT	Excreta μg. DDE	Total[1] as μg. DDT
4	18.8	0.0	0.0	0.0	0.0	18.8
8	19.4	0.0	0.4	0.0	0.0	19.8
12	17.3	0.0	1.8	0.0	0.0	19.3
24	18.4	0.0	1.0	0.0	0.0	19.5
48	14.1	0.0	1.6	1.2	1.0	18.2
72	13.9	0.0	2.0	0.0	0.0	16.1
168[2]	14.5	0.0	2.5	0.0	trace	17.3

[1] Based on molecular weight of DDT.
[2] Pupated. External=cast skin. No DDT present externally on pupa.

within 15 to 20 minutes, and continued at about the same level for about 30 minutes more, after which they slowly diminished, and at varying times between 1 and 2 hours after feeding stopped altogether. None of the larvae were observed to have any visible symptoms of poisoning 2 hours after feeding on the treated leaves.

The recovery of DDT and the metabolite DDE from larvae handled in the manner described above is shown in table 3. It is apparent from these data that the decrease in the amount of DDT remaining within the larvae is correlated with the decrease and cessation of symptoms of poisoning. The formation of DDE appears to be the first step in this detoxification of DDT by the digestive system, and is followed by further metabolism of the DDE formed, so that although production of DDE is continual, this compound does not tend to accumulate within the tissues in amounts comparable to that formed. When 10 bean beetle larvae were allowed to feed on a leaf coated with a known amount of DDE, and analyzed 7 hours later, only 22 μg. of 46 μg. DDE eaten could be recovered.

The per cent of the original dosage of DDE unaccounted for increases with time, and 16 hours after feeding 70 per cent cannot be determined by the Schechter-Haller method. Attempts to isolate and identify this missing DDE metabolite have not been successful. Neither DDT nor DDE were found in the excreta.

Red-banded Leaf Roller.—One of the anomalies of the respective toxicities of DDT and TDE (2,2-bis(*p*-chlorophenyl)-1,1-dichloroethane) is their action on various Tortricid larvae. Thus, DDT is comparatively ineffective for control of second-brood red-banded leaf roller larvae, yet TDE gives excellent control (Graham 1949; Glass & Chapman 1949). This is contrary to the usual order of toxicity, in that where DDT has been found toxic, TDE will generally be less toxic to the same species of insect. Therefore, it was thought that a study of the metabolism of both DDT and TDE by the red-banded leaf roller might prove interesting.

Egg masses and young larvae were collected in southern Illinois and Indiana during the spring and early summer, and then reared in the laboratory on apple cuttings. Last instar larvae were used in the following work.

Absorption and metabolism of DDT applied topically.—20 μg. DDT in 2 mm.[3] ethanol were placed on each larva while under light CO_2 anesthesia. When the ethanol had evaporated the larvae were placed in 125 ml. Erlenmeyer flasks with food until used in metabolism studies. This dosage did not cause any mortality of larvae or symptoms of poisoning, nor

Table 5.—Recovery of DDT and DDE from red-banded leaf roller larvae fed DDT applied to apple leaf surface. Results expressed as average recovery per larva from 2 to 3 larvae at each feeding time.

Duration of Feeding in Hours	Recovered: External μg. DDT	External μg. DDE	Internal μg. DDT	Internal μg. DDE	Excreta μg. DDT	Excreta μg. DDE	Total[1] as μg. DDT	μg. DDT Eaten
24	0.8	0.8	1.9	3.2	2.1	0.4	9.7	13.0
48	0.6	0.3	3.4	7.6	3.0	trace	15.8	18.0
72[2]	0.0	1.3	0.5	4.3	7.2	2.6	16.8	17.0
144	trace	trace	0.0	10.8	36.4	5.6	54.6	57.5
168	0.0	0.0	0.9	11.5	52.4	4.7	71.3	85.0

[1] Based on molecular weight of DDT.
[2] After 48 hours, the leaf had dried so that no further feeding occurred.

were pupation and subsequent emergence of adults affected.

At various increments of time after treatment, larvae were sacrificed for chemical analysis. The results of this experiment are shown in table 4. The rate of absorption of DDT by this insect is slow, and over 70 per cent of the original dosage of 20 μg. can be recovered externally 168 hours after treatment. DDT that is absorbed is degraded to DDE, apparently at once, since it was not possible to detect any DDT in the larval tissues. DDE appears to be retained in the body for the most part, although some excretion of this metabolite can be shown. Since DDT does not accumulate in the body, it should not appear in the excreta, and its presence in the excreta of one group must have been due to the flaking off of DDT crystals from the larvae. The decrease in total recovery at the longer time intervals may be due to degradation of DDT or DDE to compounds not responding to the Schechter color test.

Metabolism of ingested DDT.—Circles of apple leaf, 1 cm. in diameter, were covered with a deposit of 100 μg. DDT applied in ethanol solution. Each leaf circle was placed in contact with moistened cotton in the bottom of a shell vial, and one leaf roller larva introduced. The larva readily accepted the leaf as food, and was not prevented from feeding by the deposit of DDT. The amount of DDT eaten was determined by analyzing the uneaten portion of the leaf, and subtracting this from the 100 μg. originally present.

No attempts were made to prevent the larvae from making bodily contact with the DDT deposit, since this insect spins a silken web on which to rest rather than resting directly on the leaf surface. There were no symptoms of DDT poisoning in any of the larvae during these tests.

The data shown in table 5 reveal that the greater part of the DDT eaten passes through the digestive tract without being absorbed into the body, and appears unchanged in the excreta. Some degradation of DDT to DDE takes place, and there is a tendency for the degraded product to be retained in the body. Only extremely small amounts of DDT are retained in the body, and it is probable that this is held within the digestive tract. The occurrence of minute amounts of DDT and DDE externally on the larvae may be due to contact with both compounds in the excreta and contamination of the mouthparts during feeding.

Absorption and metabolism of TDE.—Because of the limited number of larvae available, it was not possible to determine the LD-50 dosage of TDE for this insect. However, it was found possible to keep a majority alive for as long as 3 days after topical application of 16.5 μg. TDE per larva. Some, but not all, larvae became excited immediately after treatment, but within 30 minutes returned to normal. Tremors developed in some of the larvae 4 hours or more after treatment while other larvae never developed tremors. Although food was available at all times during the tests, larvae were never observed to feed after topical application of TDE. As little as 2 μg. TDE topically per larva were found sufficient to prevent feeding.

Because of inconsistent extinction values of nitrated TDE at 520 mμ, it has not been found possible to accurately determine mixtures of TDE and dehydrochlorinated TDE by the Schechter method. The extinction values for identical quantities of nitrated TDE at 600 mμ, are sufficiently constant for relatively accurate results to be obtained for TDE alone, and the amounts recovered after topical application to leaf roller larvae are given in table 6. Not more than traces of dehydrochlorinated TDE could have been present.

The toxicity of TDE cannot be explained on the basis of more rapid penetration of the cuticle than is shown by DDT. In 72 hours 24 per cent of the

Table 6.—Recovery of TDE and metabolite from red-banded leaf roller larvae after topical application of 16.5 μg. TDE per larva. Results expressed as average recovery per larva from groups of 4 to 12 larvae per time interval.

Time in Hours	Condition of Larvae			Recovered			
					Internal		
	A	M	D	External μg. TDE	μg. TDE	μg. deHCl TDE	Total as μg. TDE
4	4			15.1	0.0	0.0	15.1
12	5	3		15.8	0.6	trace?	16.4
24	6	3	3	14.5	0.9	trace?	15.4
48	8	4		13.4	0.9	trace?	14.3
72	2	1	1	12.6	0.9	trace?	13.5

A = alive, M = moribund, D = dead.

Table 7.—Recovery of DDT and the metabolite DDE after topical application of 100 μg. DDT per adult *Melanoplus femur-rubrum*.

Time in Days	External μg. DDT	Internal: Cuticle at Site of Application μg. DDT	Internal: Cuticle at Site of Application μg. DDE	Internal: Rest of Cuticle μg. DDT	Internal: Rest of Cuticle μg. DDE	Internal: Gut μg. DDT	Internal: Gut μg. DDE	Internal: Rest of Tissues μg. DDT	Internal: Rest of Tissues μg. DDE	Excreta μg. DDT	Excreta μg. DDE	Total as μg. DDT
4	74.0	1.1	2.9	0	2.0	0	0	0	trace	3.2	4.6	88.8
4	91.5	2.7	1.5	0	1.5	0	0	0	0	2.0	2.8	102.6
4	64.5	3.7	2.3	0	2.0	0	0	trace	3.0	7.5	4.3	89.0
8	75.6	2.8	1.2	1.1	1.4	0	0	0	0	1.2	7.0	91.4
8	65.0	0.5	1.0	0	1.0	0	0	trace	4.6	2.5	5.7	81.7
8	86.0	0.7	2.1	trace	trace	0	0	0	0	4.3	7.4	101.5
8	56.0	1.4	1.3	0.6	1.1	0	0	0	0	1.6	3.8	66.5

dosage of TDE was absorbed, while in another group of larvae 30 per cent of the DDT was absorbed. Thus, there does not appear to be any significant difference in the rate of absorption of the two compounds.

Although TDE is continually absorbed through the cuticle, the quantity recoverable internally does not increase with time, but remains fairly constant at slightly less than 1 μg. per larva. Neither TDE nor a metabolite are found in the excreta. There is evidence that some dehydrochlorination takes place, but only traces of this metabolite are found, and the greater part of the TDE absorbed cannot be accounted for by the Schechter method. However, the continual presence of TDE within the body indicates that degradation of this compound does not take place as rapidly or as completely as the degradation of DDT.

It was not possible to determine the fate of TDE in the digestive tract, since larvae would not feed on leaves to which TDE had been applied unless the residue was less than about 3 μg. per sq. cm., and even then feeding was below normal. With a residue of 1 μg. TDE per sq. cm. of leaf surface feeding was normal, and the larvae showed no symptoms of poisoning 3 days after being placed on the leaf, but at these low concentrations not enough TDE was consumed to warrant chemical analysis.

Table 8.—Recovery of DDT and the metabolite DDE after topical application of 110 μg. DDT per adult *Melanoplus differentialis*, four days after treatment.

External μg. DDT	Internal μg. DDT	Internal μg. DDE	Excreta μg. DDT	Excreta μg. DDE	Total as μg. DDT
85.0	2.4	4.3	10.1	5.2	108.0
74.0	3.8	5.8	12.8	8.6	106.6
78.0	7.7	6.8	8.6	5.6	108.1

A deposit of 18 μg. TDE per sq. cm. of leaf caused 100 per cent mortality within 3 days, although only a trace of feeding took place on the first day, and no feeding occurred during the next two days. Thus, at concentrations of TDE above 3 μg. per sq. cm., TDE appears to have a repellent action to this insect, as well as being toxic if eaten.

GRASSHOPPERS.—The resistance of various species of grasshoppers to DDT has been demonstrated by a number of workers. Weinman *et al.* (1949) found the LD-50 value for DDT as a contact poison to be 9380 μg. per gram of grasshopper, *Melanoplus differentialis*, and the value as a stomach poison to be 2579 μg. per gram of grasshopper. This high degree of resistance indicated the desirability of tracing the path and fate of DDT in the grasshopper. Adult *M. differentialis* and *M. femur-rubrum* were used in the following studies.

Absorption and metabolism of DDT applied topically.—100 μg. DDT in 10 mm.^{3} ethanol were placed on the meso- and metanotum of each grasshopper. This was far below a lethal dosage and no symptoms of poisoning were shown by any of the insects. The data shown in table 7 are for *Melanoplus femur-rubrum*. *M. differentialis* (Table 8) gave similar results, except that nearly 100 per cent recovery was obtained, and therefore both species will be discussed together.

Absorption of DDT is slow, and even 8 days after application 70 per cent of the dosage can be recovered externally. Nonmetabolized DDT does not accumulate within the body, but in general can be recovered only from the cuticle-hypoderm at the site of application, along with the metabolite DDE. The occurrence of DDE in other areas of the cuticle-hypoderm, and the absence of

Table 9.—Recovery of DDT and the metabolite DDE from *Melanoplus sp.* fed varying amounts of DDT. Results expressed per insect.

Species	Time in Days	Dosage μg. DDT Eaten	Recovered: Gut μg. DDT	Gut μg. DDE	Body of Body μg. DDT	Body of Body μg. DDE	Excreta μg. DDT	Excreta μg. DDE	Total μg. DDT +DDE[1]	Per Cent Theor.
Melanoplus										
femur-rubrum	0.6	100	12.5	0.8	1.4	1.8	81.1	0.9	98.9	98.9
femur-rubrum	2	100	0.0	2.5	0.0	0.0	47.7	28.5	82.1	82.1
femur-rubrum	2	100	1.3	4.6	0.0	0.0	33.5	21.6	63.2	63.2
femur-rubrum	7	100	1.2	0.7	0.7	2.8	43.0	22.9	74.2	74.2
femur-rubrum	7	100	0.0	0.0	0.0	1.5	43.9	27.2	75.8	75.8
M. differentialis	1	60	2.9	9.1	0.0	0.0	35.9	7.2	56.9	94.8
differentialis	2	100	0.6	3.6	0.0	0.0	40.6	25.1	73.1	73.1
differentialis	7	100	0.6	0.4	0.3	2.3	43.5	25.1	75.3	75.3
differentialis	11	25	0.0	0.0	0.0	0.0	18.6	6.4	25.7	102.8
differentialis	11	25	0.0	0.0	0.0	trace	18.4	4.8	23.7	94.8

[1] Calculated back to DDT.

DDT in these areas, except for trace amounts, suggests that degradation takes place in the cuticle where penetration occurs and that DDE is then transported to adjacent regions. Neither DDT nor DDE can be recovered from the alimentary tract of topically treated grasshoppers. The remaining tissues of the body contain only a trace of DDT, estimated to be less than 0.1 μg. per grasshopper. DDE in small amounts also occurs in these tissues. It is apparent from the above data that DDT does not penetrate beyond the cuticle-hypoderm without being degraded, and that there is no tendency for DDT to be stored in any part of the body without first being degraded to DDE. The presence of both DDT and DDE in the excreta is difficult to explain, since neither compound can be found in the intestinal tract.

Since the per cent of total recovery of DDT and DDE from *Melanoplus femur-rubrum* decreases with time, it appears that a metabolite or metabolites not responding to the Schechter test are also formed. Recovery from *M. differentialis* in all cases was near theoretical, and this would seem to indicate that DDE is the only metabolite formed by this species.

Metabolism of ingested DDT.—Grasshoppers previously deprived of food for 24 hours to insure a good appetite were placed in individual 150 ml. Erlenmeyer flasks, and each given a small circle of bean leaf coated with a known amount of DDT applied in ethanol solution. Only those grasshoppers that consumed the entire leaf circle within 30 minutes were saved for later analysis. After consumption of the treated leaf circle, untreated bean leaves were supplied for the duration of the test. No symptoms of poisoning were shown by any of the grasshoppers.

A summary is given in table 9 of the recovery of DDT and DDE from *Melanoplus differentialis* and *M. femur-rubrum* at various times after oral ingestion of DDT. Since the results obtained are similar for both species, they will be discussed together. It is apparent that penetration of DDT through the walls of the digestive tract into the body is insignificant. The greater part of the ingested DDT passes through the digestive tract and is eliminated unchanged in the excreta. The elimination of DDT in this way is rapid, and usually over 50 per cent of that eaten will appear in the excreta within 18 hours (Table 10). Degradation of DDT takes place in the

Table 10.—Recovery of DDT and the metabolite DDE from *Melanoplus differentialis* 48 hours after oral ingestion of 100 μg. DDT per insect. Three insects in each group; results expressed per insect.

	Group 1 Anus Open μg. DDT	Group 1 Anus Open μg. DDE	Group 2 Anus Plugged μg. DDT	Group 2 Anus Plugged μg. DDE
Head	0	0.3	1.5	1.4
Fore & midgut	0	0.8	2.7	3.2
Hindgut	0	0.3	57.5	5.4
Cuticle of abdomen and thorax	0.8	3.8	4.7	5.7
Rest of tissues	0.5	2.5	2.4	3.2
Excreta at				
4 hours	16.2	2.3		
4 to 18 hours	38.4	4.0		
18 to 24 hours	2.0	0.8		
24 to 34 hours	0.0	0.4		
34 to 48 hours	4.8	3.3		
Total excreted	61.4	10.8		
Total recovered	62.7	18.5	68.8	18.9
Per cent recovery	83.5		89.8	

digestive tract, with the formation of DDE. There is some absorption of this metabolite into the body, but for the most part it is passed out with the excreta.

In most cases, it has not been possible to account for the total dosage of DDT eaten, and this may indicate the metabolism of DDT or DDE to an unidentified compound not responding to the color test.

It seemed possible that the rapid passage of DDT through the digestive tract may have been responsible for the almost complete lack of absorption by other body tissues. In the field, where grasshoppers would be continually ingesting small amounts of DDT from treated foliage, DDT would be present in the digestive tract much of the time, and absorption, even though very slight, would be continual. The following experiment was carried out to determine the effect of a high concentration of DDT within the digestive tract over a period of 2 days.

The anus of each grasshopper was closed with sealing wax and the grasshopper then allowed to consume a section of leaf on which 100 μg. DDT had been placed. The results are shown in table 10. Typical DDT symptoms did not appear in these grasshoppers, but towards the end of the 48-hour period they had assumed an abnormal position in which the head was depressed and the rest of the body elevated. An average of 8.6 μg. DDT was absorbed per grasshopper by tissues of the body other than the digestive tract, approximately 5 times that absorbed in a comparable length of time by grasshoppers able to excrete. The greater part of the recoverable DDT was concentrated in the hind intestine. Surprisingly enough, the percentage of DDE formed was the same as in those grasshoppers where rapid passage of DDT through the digestive tract was possible. This may indicate that degradation occurs in the fore and mid intestine, where little DDT remained, and that passage of DDT through this region into the hind intestine was not hindered by plugging the anus. It is also possible that DDT in the hind intestine was so mixed with the excreta formed there, that it was protected from further degradation.

DISCUSSION.—These experiments may indicate why DDT is not effective for grasshopper control. Formation of the non-toxic compound, DDE, by both the cuticle-hypoderm and the digestive tract, and the rapid passage of ingested DDT through the digestive tract without significant absorption, are factors that prevent DDT from reaching its supposed site of action, the peripheral nervous system. In the field, where feeding is such that DDT would be continually passing through the digestive tract, absorption would presumably take place continually, but the ability of the insect to degrade this compound would prevent the formation of concentrations of DDT within the tissues of the body unless extremely large amounts were ingested. Thus, kill would take place only when the dosage per acre was extremely high.

It can be shown in the laboratory that injection of DDT into *Melanoplus femur-rubrum* will produce typical DDT symptoms at dosages far below the topical and oral LD-50's reported by Weinman & Decker. As little as 2 μg. DDT per grasshopper is lethal, in contrast to dosages of over 9000 μg. topically, and over 2500 μg. orally. This confirms the results of chemical analysis; that is, DDT does not penetrate through either the cuticle or the wall of the digestive tract into other tissues of the body without first being degraded to a non-toxic compound. The failure of *Melanoplus sp.* to be poisoned by exposure to DDT would therefore seem to be due to the inability of DDT to reach its site of action, rather than to any inherent immunity to the toxic action of the compound.

The fate of DDT applied topically and orally to red-banded leaf roller larvae is similar to that found for grasshoppers. Degradation to DDE takes place in both the cuticle and the digestive tract, so that nonmetabolized DDT is prevented from penetrating into the body, and therefore from reaching its site of action. The slow rate of penetration of DDT into the cuticle and the rapid passage of ingested dosages through the digestive tract are both factors in favor of the insect.

Mexican bean beetle larvae also degrade topical and oral dosages of DDT to DDE, but in this insect metabolism of DDE also occurs with the formation of an unknown compound or compounds. Penetration of topically applied DDT is

slow, and degradation takes place at a rate sufficient to prevent accumulation of DDT within the body. It is probably for this reason that tremors are not induced by topical application of DDT. When fed DDT, bean beetle larvae show signs of poisoning for a period of time up to an hour, after which tremors cease and the insects return to normal. During this time rapid degradation of DDT takes place; within 5 minutes after feeding 35 per cent was metabolized in one case. Only extremely small amounts of DDT remain within the body after tremors cease, and 4 hours after feeding over 80 per cent may be metabolized. Unlike the grasshopper and red-banded leaf roller, Mexican bean beetle larvae do not void DDT with the excreta.

These naturally resistant insects all have the ability to degrade DDT before it can reach its site of action. Their resistance appears to be due to detoxification of DDT, rather than to a physiological immunity to the toxic action of DDT, since symptoms of poisoning will appear when the site of degradation is by-passed. As in resistant house flies, degradation of DDT in these insects takes place in the cuticle and in the digestive tract.

In the red-banded leaf roller the mechanism whereby DDT is dehydrochlorinated to DDE apparently fails to act on TDE. Larvae treated topically with TDE yield only traces of a metabolite giving a red color by the Schechter-Haller method, while non metabolized TDE can be recovered from within the body. The rate of penetration of TDE is not significantly different from that of DDT, and cannot account for the difference in toxicity. What the fate of TDE within the digestive tract would be is not known. Leaf roller larvae refuse to feed when a residue of a 3 μg./sq. cm. is present on apple leaves, and even topical application of TDE to the larvae prevents subsequent feeding. TDE therefore appears to be repellent as well as toxic if eaten. DDT shows no such repellent action.

The inability of the red-banded leaf roller to metabolize TDE at a rate sufficient to prevent it from reaching its supposed site of action, may account for the toxicity of the compound to this insect. Thus the unusual condition exists in which TDE is toxic, while DDT is almost non-toxic. Normally the reverse is true, and DDT will be more toxic than TDE to a given species of insect.

Two species of insects resistant to both DDT and TDE are the Mexican bean beetle and DDT-resistant house flies. Resistant house flies of the same strain used in previous work on DDT metabolism (Sternburg & Kearns 1950) are resistant to TDE, and able to dehydrochlorinate TDE rapidly (unpublished data). The Mexican bean beetle also has the ability to dehydrochlorinate TDE. Seven hours after consuming 140 μg. TDE, 10 larvae were found to contain 51 μg. dehydrochlorinated TDE, and only 4 μg. TDE. The rest of the dosage could not be accounted for. When fed dehydrochlorinated TDE, bean beetle larvae in 7 hours metabolized 50 μg. of 100 μg. eaten. Metabolism of TDE in this insect appears to be similar to that of DDT. First, dehydrochlorination takes place, followed by conversion to an unidentified compound or compounds.

Of the three species of insects investigated for TDE metabolism, two are resistant and both metabolize TDE rapidly. The other species is susceptible to TDE and does not rapidly metabolize this compound.

SUMMARY.—The fate of DDT in four species of naturally resistant insects has been investigated. All have the ability to degrade DDT to nontoxic metabolites.

1. *Melanoplus differentialis* degrades oral and topical dosages of DDT to DDE. Degradation takes place in the cuticle and in the digestive tract. Large amounts of DDT appear in the excreta unchanged when DDT is fed to this insect and smaller amounts of DDE are also excreted. A related species, *M. femur-rubrum*, behaves in a similar manner.

2. *Epilachna varivestis*, the Mexican bean beetle, degrades oral and topical dosages of DDT to DDE and further converts DDE to an unidentified compound or compounds. Neither DDT nor DDE are excreted.

3. *Argyrotaenia velutinana*, the red-banded leaf roller, degrades topical and oral dosages of DDT to DDE. When fed DDT, some will appear in the excreta unchanged along with DDE.

The fate of TDE in two species of insects has been investigated.

1. *Epilachna varivestis*, highly resistant to TDE, degrades this compound to

form dehydrochlorinated TDE, and further degrades this to an unidentified product.

2. *Argyrotaenia velutinana* does not degrade TDE rapidly, and only traces of a metabolite can be found. TDE can be recovered from the tissues of topically treated leaf roller larvae. TDE also has some degree of repellency to this insect, preventing the larvae from feeding on deposits of the compound.

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Chromatographic Separation of DDT and Some of Its Known and Possible Degradation Products[1]

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The colorimetric method for the quantitative determination of DDT and its analogues developed by Schechter *et al.* (1945) has been successfully used in determining microgram quantities of DDT, and several of its degradation products occurring as metabolites of DDT, in a number of species of animals. Ofner and Calvery (1945) were able to show the presence of DDA (bis-*p*-chlorophenyl acetic acid) in the urine and tissues of rabbits after the administration of DDT. They also reported the presence of a neutral metabolite of DDT, but did not identify it. In 1950, Sternburg & Kearns, and working independently, Perry and Hoskins, found that DDT-resistant houseflies were able to degrade DDT by dehydrochlorination, with the formation of a non-toxic compound, DDE (1,1-bis-(*p*-chlorophenyl)-2,2-dichloroethylene). The Schechter-Haller colorimetric method used by these workers involves intensive nitration of DDT or related compounds, followed by reaction of the nitrated products with a standardized anhydrous methanol solution of $NaOCH_3$. By this method, *p,p'*DDT yields an intense blue color with maximum absorption of light at 596 mμ. Various analogues of DDT, either known or theoretically possible as metabolites, yield red colors. The compounds considered in this report are: DDE, 4,4′-dichlorobenzophenone, 4,4′-dichlorobenzhydrol, bis-*p*-chlorophenyl methane, DDA, and *p*-chlorobenzoic acid. Since the absorption maxima of these analogues, when subjected to the Schechter-Haller method, fall within a range of 520 mμ to 540 mμ, specific identification is not possible by this means alone, nor can a mixture of two or more of the degradation products be determined. A mixture of DDT with one of these degradation products can easily be measured by this method, but not if more than one compound producing a red color is present in mixture.

The principle metabolite of DDT produced by insects would appear to be DDE. In fact, in most cases it would appear to be the only degradation product which responds to the Schechter-Haller test. However, in the course of studies on the fate of DDT in insects other than the housefly, and under certain conditions, metabo-

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lites other than DDE may appear as a result of treatment with DDT. One of these compounds produces a red color when subjected to the Schechter-Haller test. However, it has an absorption maximum at 540 mμ, compared to 520 mμ. for DDE treated in the same manner. The estimation of DDE in the presence of this unknown product would appear impossible in mixture, especially if the two should occur with DDT. The chromatographic method described in this paper has been found adaptable to the separation of DDE from DDT, from the unidentified metabolite mentioned, and from a number of DDT analogues theoretically possible as metabolites, but not as yet found in insect tissues.

As more species of insects are studied, it appears that the conversion of DDT to DDA, the principle metabolic end product of DDT in vertebrates, is of minor importance in insects. The occurrence of DDA in a resistant strain of housefly was reported in a single analysis by Sternburg *et al.* (1950). This, in all probability, was the result of a fault in the extraction process; repeated attempts have failed to confirm the presence of DDA. No other instance of the recovery of DDA from insects after treatment with DDT has been reported. Whenever an investigation of the fate of DDT within an insect species not previously studied is begun, the presence or absence of DDA as a metabolite should be determined. If it can be shown that this metabolite is not present, this step may be omitted in subsequent experiments with considerable saving in time and effort.

The procedures described in this report have been found adaptable to the study of DDT metabolism in the following species of insects: *Musca domestica* L., *Blattella germanica* (L.), *Periplaneta americana* (L.), *Melanoplus differentialis* (Thomas), *M. femur-rubrum* (DeGeer), *Epilachna varivestis* Mulsant, *Argyrotaenia velutinana* (Walker) and *Sarcophaga crassipalpis* Macq. The optical densities of the colored solutions were measured with the Beckman model DU quartz spectrophotometer, using standard 1 cm. Corex cells. The total volume of fluid for color development of each sample was 3.3 ml. Chemically pure *p,p'*-isomers of each compound, the melting points of which agreed with those in the literature, were used throughout this work.

EXTRACTION OF DDT AND VARIOUS KNOWN AND SUSPECTED METABOLITES.—The method of extraction of DDT-treated insects is essentially the same as used by Sternburg *et al.* (1950) in studies of DDT metabolism in the housefly. In cases where DDA and *p*-chlorobenzoic acid may be suspected as possible metabolites of DDT, it is important to acidify the sample of insects before extraction with a suitable solvent. The sample of insects may be ground with mortar and pestle, or in the case of hard bodied insects such as the American roach, in a Waring blender. The grinding process may in any case be aided by the addition of anhydrous Na_2SO_4 and a small amount of the solvent to be used in the extraction process. The amount of solvent used in the initial extraction may vary through wide limits. A convenient quantity may be stated as 25 ml. to each gram of insect tissue, with a sufficient quantity of sodium sulphate to effect a good degree of dehydration. After a period of 5 to 10 minutes of agitation of macerated insects and sodium sulphate in the solvent, the latter is decanted through filter paper into a 125 ml. separatory funnel. This process

Table 1.—Recovery from mixtures of 25 μg. each of DDT, DDE, 4,4'-dichlorobenzophenone and 4,4'-dichlorobenzhydrol from 2 grams of macerated German roaches.

Eluate	Sample Number						Compound	Range in Per Cent Recovery
	1	2	3	4	5	6		
Pet. ether	19.8	18.2	20.8	25.0	20.2	22.2	μg. DDE	95–100 DDE
	0.3	0.5	0.3	0.0	0.5	5.6	μg. DDT	
CCl_4	5.1	6.1	3.9	0.0	3.5	2.1	μg. DDE	92–99 DDT
	23.3	23.2	22.7	23.5	23.5	19.3	μg. DDT	
Benzene	23.1	24.2	24.1	22.3	22.1	23.8	μg. 4,4'-dichlorobenzophenone	88 to 96
Ethyl ether	23.4	23.6	25.0	24.5	24.4	18.5	μg. 4,4'-dichlorobenzhydrol	74–100

Table 2.—Recovery from mixtures of 5 μg. each of DDT, DDE, 4,4′-dichlorobenzophenone and 4,4′-dichlorobenzhydrol from 2 grams of macerated roaches.

Eluate	Sample Number				Compound	Range in Per Cent Recovery
	1	2	3	4		
Pet. ether	4.8	5.2	4.8	4.9	μg. DDE	96–104
CCl_4	5.0	4.6	5.1	5.0	μg. DDT	92–102
Benzene	5.1	4.9	4.9	4.8	μg. 4,4′-dichlorobenzophenone	96–101
Ethyl ether	5.2	5.2	5.1	4.8	μg. 4,4′-dichlorobenzhydrol	96–104

is then twice repeated and each decantation of solvent added to the first. Such an extraction method has been found adequate to remove 95 per cent or more of DDT and suspected metabolites from macerated insects when these compounds are present in amounts of 5 micrograms or more, and when the weight of insect tissue totals as much as 2 grams. It is probable that a wide choice of solvents might be successfully used for extraction purposes, but we chose ethyl ether principally because it could be sufficiently and readily purified to meet our needs by simple distillation.

Assuming that DDA or *p*-chlorobenzoic acid may be present in the extract they may be removed by alkaline extraction and quantitatively determined as described by Schechter *et al.* (1945). After alkaline extraction the solvent remaining should be carefully washed to remove traces of alkali, as the latter may result in conversion of DDT to DDE when the solvent is subsequently removed. If it can be shown that DDA and *p*-chlorobenzoic acid are not present, this step may be omitted in subsequent experiments.

Since DDA and *p*-chlorobenzoic acid can be separated from other degradation products of DDT by the method described above, and since they apparently are not produced by insects, these compounds have not been considered in the chromatographic method described below.

CHROMATOGRAPHIC SEPARATION OF VARIOUS DDT ANALOGUES.—The method to be described is suitable for the separation of microgram quantities of DDE, DDT, 4,4′-dichlorobenzophenone, 4,4′-dichlorobenzhydrol, and bis-*p*-chlorophenyl methane, in the presence of ether soluble substances, from up to 2 grams of insect tissue. After separation, the compounds are quantitatively determined by the Schechter-Haller method. Recoveries of known amounts of these compounds added to macerated insect tissue and subjected to this procedure range between 90 and 100 per cent.

In actual metabolism studies, only DDE has been recovered with reasonable certainty. In the case of two insects investigated, *Sarcophaga crassipalpis* and *Periplaneta americana*, a metabolite of DDT that behaves in a manner similar to that of 4,4′-dichlorobenzhydrol can be isolated, but due to the presence of interfering materials from insect tissue it has not been specifically identified. Neither bis-*p*-chlorophenyl methane nor 4,4′-dichlorobenzophenone have yet been found in the tissues of insects treated with DDT.

Table 3.—Recovery of 25 μg. of several compounds passed through alumina individually.

Eluate	Compound				
	μg. DDE	μg. DDT	μg. Dichlorobenzophenone	μg. Dichlorobenzhydrol	μg. Bis-*p*-chlorophenyl Methane
Pet. ether	22.5	trace	0	0	21.3
CCl_4	1.0	23.5	0	0	2.0
Benzene	0	0	23.2	0	0
Ethyl ether	0	0	trace	24.3	0
Total recovered	23.5	23.5	23.2	24.3	23.3
% recovery	94	94	93	97	93

REAGENTS.

1. Petroleum ether, 30–60° C. boiling range.
2. Carbon tetrachloride.
3. Benzene. A.C.S. grade.
4. Diethyl ether, U.S.P. Distilled once from all-glass apparatus.
5. Activated alumina. Alcoa, grade E-20, mesh 80–200, or mesh 48–100.

Occasional cans of activated alumina apparently are contaminated by substances capable of catalytically dehydrochlorinating DDT. For this reason, whenever a new supply of alumina is obtained, tests should be made to determine if it is suitable for use. This can easily be done by determining the recovery of 50 μg. DDT after passage through the alumina column in the manner described below. There should be no traces of DDE, if the alumina is not contaminated.

METHOD.—A chromatographic tube with 12 mm. inside diameter is plugged with a small wad of glass wool, and activated alumina lightly packed into the tube, to a depth of 5 cm. (If 48–100 mesh alumina is used, the depth should be 6 cm.) The solvent is carefully evaporated from the insect extract to be analyzed and the residue taken up in 5 ml. petroleum ether and carefully introduced into the column. This is repeated twice more with 5 ml. portions of petroleum ether, each added to the column as soon as the preceding one has sunk into the alumina. This is followed by 60 ml. petroleum ether. The entire petroleum ether eluate is collected in one flask. If DDE is present in the insect extract, it will appear in this eluate. When the last of the petroleum ether has sunk into the alumina, a clean flask is placed under the column and 25 ml. CCl_4 passed through the alumina. The CCl_4 eluate will contain DDT, if present. When all the CCl_4 has been collected, another flask is placed under the column and 65 ml. benzene passed through the alumina. The benzene eluate will contain 4,4′-dichlorobenzophenone, if present. Another flask is then placed beneath the column and 50 ml. diethyl ether passed through the alumina. (Acetone may be substituted for ethyl ether.) This eluate will contain 4,4′-dichlorobenzhydrol, if present.

The solvents are evaporated from each of the four flasks and analyses made by the Schechter-Haller method. Care must be taken to avoid volatilization of the compounds during evaporating of the solvents. In practice, it has been found that most of the solvent can be safely evaporated by means of heat from a steam bath plus a moderate air stream. The last 4 or 5 ml. of solvent should be evaporated with an air stream only.

Bis-*p*-chlorophenyl methane, if present, will appear in the petroleum ether eluate along with DDE. By refluxing the residue from this eluate in ethylene glycol and KOH to convert DDE to DDA, and extraction of the reaction mixture with ethyl ether, bis-*p*-chlorophenyl methane can be separated from the water soluble potassium salt of DDA. Both compounds can then be determined by the usual Schechter-Haller method. None of the insects so far investigated has been found to form bis-*p*-chlorophenyl methane after treatment with DDT, and therefore this step may ordinarily be omitted.

DISCUSSION.—A 75 ml. quantity of petroleum ether is sufficient to elute most of the DDE present, while only traces of DDT are eluted. Neither 4,4′-dichlorobenzophenone nor 4,4′-dichlorobenzyhydrol are eluted by this volume of petroleum ether.

A 25 ml. quantity of CCl_4 elutes DDT from the column completely. Any DDE not eluted by the petroleum ether will also appear in the CCl_4 eluate. Neither 4,4′-dichlorobenzophenone nor 4,4′-dichlorobenzhydrol will be eluted by 25 ml. CCl_4.

Unless there is some specific reason for separation of DDE from DDT, the use of petroleum ether may be omitted, and the process started with CCl_4. The two compounds may then be determined in mixture in the CCl_4 eluate. The volumes of solvents used are not affected by eliminating the petroleum ether elution.

A 65 ml. quantity of benzene almost completely elutes 4,4′-dichlorobenzophenone, while 4,4′-dichlorobenzhydrol will remain in the column.

A 50 ml. quantity of ethyl ether or acetone is sufficient to elute any 4,4′-dichlorobenzhydrol present. Most of the insect fat will also appear in this fraction.

It is important that the order of solvents be as given above, since each succeeding solvent can cause elution of any

compound removed by a preceding solvent in this process.

The amount of fat from up to 2 grams of insect tissue does not interfere with the separation of the compounds. The petroleum ether and CCl_4 eluates are practically fat free. A small amount of fat elutes with benzene, while the remainder comes through the column with ethyl ether or acetone. Blanks run with untreated insect tissue are colorless for the petroleum ether and CCl_4 eluates subjected to the Schechter-Haller method. A pale yellow color, giving a small and fairly constant interference for a given quantity of insect material, is present in blanks from the benzene and ethyl ether or acetone eluates.

Mixtures of 25 micrograms each of DDE, DDT, 4,4′-dichlorobenzophenone and 4,4′-dichlorobenzhydrol, added to the macerated tissues from 2 grams of *Blattella germanica*, and subjected to this method, gave results as shown in table 1. Recoveries from mixtures of 5 micrograms of each of the four compounds added to the macerated tissues from 2 grams of *B. germanica* are shown in table 2. Typical results obtained by elution of each compound individually through the column are shown in table 3

SUMMARY.—By a succession of solvents, DDE, DDT, 4,4′-dichlorobenzophenone and 4,4′-dichlorobenzhydrol are eluted separately from an alumina column. Fat from 2 grams of insect tissue does not interfere, and DDE and DDT are isolated almost fat free. Recoveries of microgram quantities of DDT and DDE range between 90 and 100 per cent.

Recovery of 4,4′-dichlorobenzophenone and 4,4′-dichlorobenzhydrol may occasionally be low, but generally will be better than 90 per cent.

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Phosphorus-32 Labeling of the Screw-worm Fly

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It was demonstrated by Bushland & Hopkins (1951) that females of the screw-worm fly *Callitroga americana* mated only one time under laboratory conditions. They found that flies could be sterilized by treating them in the pupal stage with x-rays. In their work with caged populations whereby normal insects were outnumbered by sterilized flies, the majority of the normal females appeared to have mated with sterilized males, as they laid infertile eggs.

Field tests were planned to find whether natural screw-worm populations could be reduced through the release of larger numbers of sterilized insects. To distinguish between the normal population and the released insects it was essential that the released flies be distinctively marked. Formerly such marking has been done through the use of dyes or colored dusts made to adhere to the bodies of the released insects, but recently investigators have found it much more practical to mark flies with phosphorus 32.

Hoffman *et al.* (1951) showed that the blow fly *Phaenicia sericata* (Meig) could be made radioactive either by feeding P-32 in sugar solution to the adults or by rearing larvae in a ground beef medium to which P-32 had been added. They also found that eggs laid by those radioactive flies were sufficiently radioactive to be identified. Those authors suggested that screw-worm flies could be similarly tagged with P-32.

[1] Bureau of Animal Industry.
[2] Bureau of Entomology and Plant Quarantine.

Table 1.—Counting rates produced in larvae and adults of *Callitroga americana* by rearing in small lots and with varying concentrations of radioactive phosphorus 32.

Concentration of Phosphorus 32 in Medium, Microcuries per Gram of Medium	Larvae: Net Counts per Minute, (in Thousands) at the Age in Days Indicated, per Larva						Adults: Net Counts per Minute, (in Thousands), per Fly, at Indicated Days After Emerging			
	1	2	3	4	5	6	1	7	13	20
8.0	2.05	9.33	39.49	170.86	184.14	353.96	260.28	117.26	—	—
4.0	1.18	5.97	25.98	68.44	168.26	182.53	122.33	58.48	—	—
2.0	.453	3.26	11.03	45.31	104.65	116.90	70.34	26.97	—	—
1.0	.22	1.34	9.43	30.75	41.71	38.15	20.81	—	—	—
0.5	.15	.82	4.75	14.59	24.53	17.47	14.28	4.76	3.35	1.77
0.2	.05	.26	1.22	4.69	9.28	7.29	4.49	2.14	1.57	—
0.1	.02	.14	.41	1.49	3.82	3.66	3.74	1.70	—	—
0.05	.01	.13	.52	1.50	2.78	2.16	1.72	.55	.43	—
0.02	.007	.04	.15	.63	.84	1.00	.61	—	—	—
0.01	.01	.01	.08	.23	.44	.54	.32	—	—	—

This paper describes experiments made to develop a technique for marking screw-worms with radioactive phosphorus so that released flies and their eggs could be distinguished from the normal population, using portable radiation monitoring equipment, in field studies on the biology and control of this insect.

Radioactive Phosphorus.—The phosphorus used in these experiments was the radioactive isotope 32 produced by the nuclear reactors of the Oak Ridge National Laboratories. As received from those laboratories the phosphorus 32 was in the form of phosphoric acid. The specific activity was consistently 40 millicuries per milligram.

No chemical alterations of the material were made after its receipt. The original samples was in every case simply diluted with distilled water to the concentrations desired for addition to media, for intravenous injection or for assay.

Radiation Measuring Equipment.—To obtain direct comparisons of counting rates a standard scaler equipped with a shielded sample changer of fixed geometry was used. The scaler was equipped with a mica end-window Geiger tube, the mica window having a thickness of 1.5 milligrams per square centimeter. Each specimen to be counted was placed in a steel cup 1 inch in diameter and 7 millimeters deep. In position the rim of the cup was 3 millimeters from the end-window of the tube, there being a maximum of 10 millimeters distance from the end-window to the bottom of the cup.

The counting rates reported here are for the intact egg, larva or fly as would be the case in the use of field equipment. Most of the counting was done to plus or minus one per cent accuracy. Individual variations greatly exceeded this amount.

A portable radiation monitor, using a glass wall Geiger tube of 35 milligrams per square centimeter thickness was used to compare counting rates obtained. It was found that this monitor was capable of recording 25 per cent of the counts received by the scaler.

Criterion for Labeling.—To be suitable for detection with portable radiation monitoring equipment the specimen should register a counting rate of at least the background counting rate. As a practical objective a net counting rate of at least 50 counts per minute was selected. Using field equipment having an efficiency of only 25 per cent of that of the scaler, this would require a minimum of 200 counts per minute as registered by the scaler. This criterion of a minimum of 200 counts per minute, net, by scaler count, was applied to the data obtained for flies, egg masses and larvae. This minimum, in the case of a fly, must obtain on the final day of life of that fly. A period of 4 weeks was considered as a lifetime for the purposes of these experiments.

Rearing Methods.—It appeared that the release of screw-worms in the field would be best accomplished by distributing the pupae and allowing the insects to emerge normally; therefore, it was necessary that the flies take up the radioactive phosphorus as larvae. Screw-worms are most economically produced by rearing them in the medium described by Melvin

Table 2.—Counting rates produced in larvae and adults of *Callitroga americana* by rearing in medium containing phosphorus 32 for three days and then transferring the larvae to ordinary media to complete development.

Concentration of Phosphorus 32 in Starting Medium, Microcuries	Larvae: Counts per Minute per Larva (in Thousands), at Time Indicated		Adults: Counts per Minute per Fly (in Thousands), on Indicated Day After Emergence		
	1 Day Before Transfer	2 Days After Transfer	1	7	13
0.2	1.37	1.98	1.83	.59	.39
0.5	3.75	6.97	7.08	2.64	1.24
1.0	10.26	14.55	16.02	5.47	2.71
2.0	6.16	30.90	24.82	8.02	4.83

& Bushland (1941), but the insects grown on that medium might not respond exactly like those reared in wounds of warm-blooded animals as all natural populations develop, so it was also necessary to devise a method for producing radioactive flies from larvae reared in wounds on sheep and goats.

USE OF ARTIFICIAL MEDIUM.—*Preliminary experiments.*—To find the levels of radioactive phosphorus required for adequate labeling, small numbers of *Callitroga americana* were reared in wide-mouth pint mason jars containing the medium described by Bushland (1940). The medium consisted of water, 50 ml., gound lean beef, 75 gms., citrated beef blood, 25 ml., and formaldehyde (37%), 0.3 ml. Sufficient radioactive phosphoric acid was added to obtain concentrations of 0.01, 0.02, 0.05, 0.1, 2.0, 4.0, and 8.0 microcuries per gram of medium for the various lots. Jars of radioactive rearing medium were prepared by adding the desired amount of radioactive phosphoric acid to the water, then adding the formaldehyde and stirring. The blood and ground beef were then added and thoroughly mixed.

Table 3.—Counting rates produced in larvae of *Callitroga americana* by starting them in normal medium and then transferring them to medium containing radioactive phosphorus.

Concentration of Phosphorus 32 in Finishing Medium, Microcuries per Gram of Medium	Larvae: Counts per Minute per Larva (in Thousands), After Indicated Number of Hours of Exposure to P-32 before Pupation	
	36	60
0.005	0.20	0.25
0.01	0.53	0.53
0.03	0.71	1.14
0.06	1.77	2.31
0.12	3.26	4.07
0.3	6.69	10.61

Approximately 100 newly hatched larvae of *Callitroga americana* were introduced into each jar. On the fourth day of development the larvae were transferred to fresh jars of medium containing the same concentrations of phosphorus 32. The larvae finished feeding when 6 days old and crawled from the jars which were tilted over dry sand. The insects pupated within 24 hours. The pupae were held in damp sand at room temperature until the adults emerged a week later. On emergence from the puparia the flies were placed in suitable cages and kept fed and watered until all had died.

Data on this experiment are assembled in table 1. Counting rates of the flies on emergence ranged from 323 counts per minute per fly at the 0.01 microcurie per gram level to 260,281 counts per minute per fly at the 8 microcurie per gram level. Additional counts were made at approximately weekly intervals so long as the flies lived.

From this experiment it appeared that the 0.2 and 0.5 microcurie per gram levels would provide the best labeling at the lowest cost.

In following the daily increases in counting rates it was apparent that the larvae in the starting media containing the higher concentrations of P-32 were showing high counting rates by the time they were ready to transfer to new media.

A portion of the foregoing experiment was then repeated, using 0.2, 0.5, 1.0 and 2.0 microcuries of phosphorus 32 per gram of medium to start the larvae. Instead of continuing the phosphorus 32 dosage in the second change of media the larvae were transferred on the third day to ordi-

Table 4.—Counting rates produced in larvae and adults of *Callitroga americana* in large scale rearing in phosphorus 32 for field release.

Concentration of Phosphorus 32 per Gram of Medium, in Microcuries	Larvae: Counts per minute per Larva (in Thousands), on Day of Pupation	Adults: Counts per Minute per Fly, (in Thousands), on Indicated Day After Emergence			
		1	6	14	21
First series					
0.2	8.12	5.91	3.21	0.624	0.692
0.5	19.68	12.60	7.54	2.15	1.41
1.0	35.54	22.98	14.68	5.91	3.28
Second series					
0.2	8.57	5.61	2.54	1.35	0.92
0.5	19.06	15.93	6.99	3.58	2.09
Third series					
0.2	7.41	5.50	3.30	released	released
Fourth series					
0.2	9.53	6.23	released		
Fifth series	6.65	3.56	released		
Sixth series	7.88	4.76	released		
Seventh series	6.72	4.58	released		

nary medium and allowed to finish development. Remaining procedure was the same as in the foregoing experiment. Table 2 gives the results obtained with this method. This method would give acceptable labeling at the 0.5 microcurie per gram level and above.

The procedure of the foregoing experiment was reversed in a third experiment, the larvae being started in plain media and then transferred to radioactive media to complete their development. Counting rates for these larvae are given in table 3. This method, while capable of producing flies carrying sufficient radioactivity to be identifiable, does not produce uniform labeling. This is because the larvae complete feeding and migrate from the medium in 24 to 60 hours after the transfer and the extent of labeling varies proportionally.

Table 5.—Distribution of phosphorus 32 in larvae of *Callitroga americana* after feeding to maturity on P-32 medium.

Tissue Group	Phorphorus 32, in Percentage	
	Larva with Extensive Fat Bodies	Larva with Relatively Few Fat Bodies
Fat bodies	54.4	30.5
Muscles	19.6	28.1
Tracheal system	1.4	1.3
Digestive tract	13.0	22.3
Cuticle	5.2	8.5
Central nervous system	0.4	1.1
Heart	0.5	0.3
Miscellaneous trimmings	5.5	7.9

Rearing of Larger Numbers.—From the foregoing experiments we concluded that rearing *Callitroga americana* throughout the larval stage in medium containing 0.2 microcurie of P-32 per gram would produce uniformly labeled flies with counting rates safely in excess of the minimum we had set. Insufficient numbers of flies were produced in these initial experiments to develop data on longevity and fertility. The larger scale experiments to be described were set up to determine these points and to reinforce the conclusions already made as to the suitability of the labeling.

In each of these experiments approximately 2000 larvae were reared in media containing 0.5 and 0.2 microcurie of P-32 per gram. In one series an additional lot was reared in medium containing 1.0

Table 6.—Distribution of phosphorus 32 in adults of *Callitroga americana* reared in a medium containing P-32.

Body Portion	Phosphorus 32 in Percentage	
	Reared in Medium Containing 0.5 Microcurie P-32 per Gram	Reared in Medium Containing 0.2 Microcurie P-32 per Gram
Wings	2.6	2.0
Legs	8.6	9.2
Head	17.6	15.3
Thorax	33.9	36.5
Abdomen	37.2	36.8

Table 7.—Counting rates of eggs and larvae produced from *Callitroga americana* reared on medium containing phosphorus 32.

CONCENTRATION OF PHOSPHORUS 32 IN MEDIUM USED TO REAR FLIES, MICROCURIES PER GRAM OF MEDIUM	NET COUNT PER MINUTE PER 100	
	Eggs	Larvae
.05	152	136
.1	370	340
.2	580[1]	850[1]
.5	1200	1000
2.0	7700	—

[1] Such discrepancies occur because the larvae counted were not from the eggs counted.

microcurie per gram. In each series one lot of larvae was grown in non-radioactive media. The medium was of the following proportions: water, 500 ml.; ground lean beef, 500 gms.; citrated beef blood, 250 ml.; and formaldehyde, 3.0 ml.

Each lot of 2000 larvae was started in 1250 grams of medium and transferred on the third day to 5000 grams of the same medium to complete development. The larvae were allowed to pupate in sand and the emerging flies were then maintained in screen-wire cages.

The flies were permitted to oviposit and the eggs allowed to hatch. There was no difference in either egg laying capacity or fertility between the controls and any of the exposed groups. There were no significant differences in longevity between the control and treated flies.

Counting data obtained in these experiments are given in table 4. We found that the degree of labeling was substantially that obtained in the previous small-lot series. Such physiological factors as speed of development may be expected to produce as much as ten per cent variation between similarly exposed individuals or groups. The counting rates given in the tables are averages of three or more flies or larvae at each counting. The counting rates obtained are considerably decreased when the larvae are crowded in the medium.

MISCELLANEOUS OBSERVATIONS.—Determinations were made of the regional distribution of phosphorus 32 in larvae and flies. Larvae were dissected when ready to pupate and separated into cuticle, muscle, tracheal system, digestive tract and fat bodies. Counting rates were determined for each of these components.

Table 8.—Counting rates produced by rearing *Callitroga americana* in sheep and goats given intravenous doses of phosphorus 32 at the rate of 0.1 microcurie per gram of body weight.

NUMBER OF DAYS IN HOST	COUNTS PER MINUTE PER LARVA				
	Sheep		Goats		
	1	2	1	2	3[1]
1	37	—	20	24	10
2	581	—	—	—	—
3	2125	—	—	—	—
4	3026	—	—	—	—
5	3920	4260	2625	2721	1736
6	pupae	pupae	—	—	—
7			2886	2326	1590

DAYS AFTER EMERGENCE	COUNTS PER MINUTE PER FLY	
	Sheep 1	Pooled Flies from Goats
1	2534	1260
7	1289	743
14	659	363
21	440	281

[1] This goat received 0.06 microcurie per gram weight.

Larvae with extensive fat bodies and others with comparatively few fat bodies were dissected. The results are given in terms of percentage in table 5. Because flies caught in traps dry rapidly and become brittle, certain portions of the body might cause confusion in identification. Flies were cut into head, thoracic, abdominal, wing and leg sections. The distribution of P-32 in these portions is given in table 6. This distribution is in general agreement with that found for fragments of house flies by Hoffman *et al.* (1951).

The activity of phosphorus 32 in eggs and larvae produced by adults reared in radioactive medium was measured in several cases. The counting rates for eggs and larvae are given in table 7. These counting rates indicate that it is possible to determine by means of a radiation monitor whether or not masses of eggs or larvae are from flies reared on a medium containing 0.05 microcurie or more of phosphorus 32 per gram.

REARING OF *Callitroga americana* IN SHEEP AND GOATS.—Two sheep and two goats were given, intravenously, diluted phosphoric acid (P-32) at the rate of 0.1 microcurie per gram of body weight. One goat was given 0.06 microcurie per gram of body weight. The solution used for injection was prepared by diluting the con-

centrated phosphoric acid (P-32) with distilled water to obtain a final concentration of 0.4 millicurie per milliliter.

On the day following the injection the animals were wounded and newly-hatched larvae of *Callitroga americana* were placed in the wounds. The larvae developed, pupated and flies emerged normally from all animals except one sheep. The larvae from this sheep were lost when they emerged earlier than had been anticipated. Substantial counting rates were shown by the emerging flies from all animals, those from the sheep being higher than those from the goats. Counting rates are given in table 8.

It is thus possible to label *Callitroga americana* with phosphorus 32 by administering the P-32 intravenously to the animal used as the host. The relatively large amounts of P-32 required to produce even moderate labeling as compared with the number of adults obtained makes this procedure expensive and therefore impracticable except for special studies.

CONCLUSIONS.—Adult *Callitroga americana* labeled with phosphorus 32 are easily obtained by rearing in an artificial medium to which phosphoric acid (P-32) has been added. The intensity of radiation carried by the flies can be varied over a wide range by varying the content of phosphoric acid (P-32).

There is no apparent harm to the flies at dosages as high as 1.0 microcurie per gram of medium. This intensity is far more than should ever be required for labeling experiments.

To minimize contamination of equipment the larvae may be started in a radioactive medium containing 0.5 microcurie or more of phosphorus 32 per gram and transferred to ordinary medium to complete development. Reversal of the procedure does not produce uniform results.

Callitroga americana may also be labeled by rearing in natural hosts such as sheep and goats by administering phosphoric acid (P-32) intravenously to the host.

Egg masses from the flies reared in medium containing 0.2 microcurie or more of phosphorus 32 per gram are readily identifiable with field radiation monitoring equipment. The same is true of egg masses from flies reared on sheep and goats given 0.1 microcurie or more of phosphorus 32 per gram of body weight intravenously.

The biological half-life of phosphorus 32 in these experiments was approximately 7 days, with considerable variation.

SUMMARY.—Experiments are described in which *Callitroga americana* were produced, labeled with phosphorus 32, by rearing in artificial medium containing P-32, and in natural hosts by administering phosphoric acid (P-32) to the host. Several dosages and variations of technique are described. The regional distribution of P-32 in larvae and adults was determined and the counting rates of eggs and larvae from flies reared on radioactive media are given.

Callitroga americana is easily labeled with phosphorus 32. Only minor manipulation of the phosphorus 32 is required.

For field studies a concentration of 0.2 microcurie of P-32 per gram of artificial medium appears to give adequate labeling for positive identification of flies and their egg masses.

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Laboratory Studies of the False Stable Fly

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The false stable fly, *Muscina stabulans* (Fallén) is often found in association with the house fly, *Musca domestica* L. around dairy barns, hog farms, poultry ranches, and horse stables. In addition to the above, a number of other habitats have been reported for this fly. Curran (1942) and Satterthwait (1943) reported *M. stabulans* as being parasitic on Lepidopterous larvae. Nelson (1938) found larvae of *M. stabulans* in overripe tomatoes in a cannery. Brooks (1951) indicated that *M. stabulans* attacks cruciferous crops in Canada.

The false stable fly has been reported by Ruhland & Huddleson (1941) as being a carrier of *Brucella abortus*, the organism responsible for undulant fever. Bang & Glaser (1943) found that poliomyelitis virus could survive in *Muscina stabulans* for at least 2 days. James (1947) records this fly as being one of the species responsible for intestinal myiasis in man.

Because of the development of house fly resistance to various insecticides, the status of the false stable fly in situations where house flies have become resistant is of interest. Although little has been reported on the life history, habits, and especially on the effect of insecticides on this fly, from the foregoing it would seem that *Muscina stabulans* is of sufficient importance to be considered in such investigations.

REARING PROCEDURE.—Adult false stable flies were collected by net in the field and were placed in a 12-inch cube screened cage in the laboratory. A cotton pad soaked in 20-per cent sugar solution and another soaked in equal parts of evaporated milk and water were provided as a source of food, and the latter served as the oviposition medium as well. Eggs were collected from the milk pad daily and placed in larval medium.

The larval rearing method was modified from a method[2] used for rearing house flies (Anon. 1950). Gallon glass mayonnaise jars served as containers for the medium and the jar tops were covered with muslin squares held in place by rubber bands. Each jar contained the following well-mixed ingredients: 12.5 ml. concentrated diamalt, 597.5 ml. water, 30 g. dried brewers yeast, 80 g. alfalfa meal, and 240 g. milled red wheat bran.

After completing four generations using the medium described above, the fifth generation females failed to produce eggs and the colony was lost. Previous to the fifth generation, the females had oviposited copiously on the milk pads. Difficulty in obtaining eggs from *Muscina stabulans* in captivity has been previously reported by Portchinsky (1913).

LIFE HISTORY STUDIES UNDER LABORATORY CONDITIONS.—The life history studies on *Muscina stabulans* were conducted in a constant temperature and humidity rearing room. The temperature was held at 80.0° ± 2.5° F. and the relative humidity at 60.0 ± 2.5 per cent. Under these conditions the preoviposition period lasted from 6 to 8 days. A complete life cycle from egg to egg required from 20 to 25 days.

Muscina stabulans tended to deposit its eggs in a spread-out manner on the milk pads. However, when oviposition

[1] The helpful suggestions of R. B. March in conducting this study are gratefully acknowledged.

[2] The standard Chemical Specialties Manufacturers Association.

Table 1.—Twenty-four hour per cent mortalities for male and female false stable flies, *Muscina stabulans* (Fallén).

Dose in Microg. per Fly	Per Cent Mortality	
	Male	Female
DDT		
0.01	15	17
0.02	48	25
0.04	88	78
0.06	93	68
0.1	100	100
Lindane		
0.002	10	10
0.004	53	45
0.005	85	65
0.006	100	100
Methoxychlor		
0.001	10	15
0.002	15	20
0.005	20	25
0.01	60	30
0.05	100	100

was heavy, clusters of eggs occurred. The eggs measured 1.1 mm. in length, were elongate, white, and ribbed longitudinally. A majority of the eggs usually hatched within 24 hours of oviposition.

The larval stage lasted from 6 to 8 days and the pupal stage lasted from 8 to 9 days. Average pupal weight was 28.61 mg. Three-day-old flies averaged 20.6 mg. in weight per female and 22.0 mg. per male.

A 20-per cent sugar solution was fed to adult flies used in making longevity studies. On this diet males lived from 12 to 21 days and females lived from 12 to 24 days.

TOXICITY STUDIES.—Toxicological tests were conducted with progeny of *Muscina stabulans* adults which were collected at a dairy where house flies had become resistant to DDT, methoxychlor, and lindane.

In the laboratory, adult flies were held for 3 days after emergence and fed a 20-per cent sugar solution before being tested. The insecticides were applied as weight per volume acetone solutions using the standard procedure for topical application of micro-drops (March & Metcalf 1949). Each fly was treated with an individual one-cubic millimeter drop. Groups of 20 flies were tested for each compound, each test being replicated three times. After treatment the flies were held at 60° F. and 60 per cent relative humidity. Mortality was determined after 24 hours.

The results of tests conducted with DDT, methoxychlor, and lindane on both male and female false stable flies are given in table 1. The LD_{50} values for a resistant and a nonresistant house fly strain are given in table 2 for comparison with LD_{50} values for the false stable fly. In table 2 only females are compared.

Table 2.—Comparative LD_{50} values in micrograms per female fly for the false stable fly, a nonresistant housefly strain, and a resistant house fly strain.

	LD_{50} MICROG. PER FEMALE FLY		
	DDT	Lindane	Methoxychlor
False stable fly	0.027	0.0041	0.014
Nonresistant house fly	0.033	0.01	0.068
Resistant house fly[1]	9.5	0.13	1.3

[1] Collection source same as for false stable fly.

These tests show that the false stable fly is more susceptible to DDT, lindane, and methoxychlor than either a nonresistant house fly strain from the laboratory or a resistant house fly strain from the same collection source. It is difficult to understand how *Muscina stabulans* has remained as susceptible as as this at a dairy where DDT, methoxychlor, and lindane have all been used extensively for house fly control, and where the house fly strain shows relatively high levels of resistance. It is possible that a peculiarity of resting habits may be responsible, or perhaps the adults which were collected had just moved into the dairy from another source where they were not exposed to insecticides. Even their high susceptibility could be responsible in that complete mortality of all adults contacting a treated surface would preclude selection for resistance. The fact that the false stable fly strain is about as susceptible to DDT as the nonresistant strain, yet is considerably more susceptible to methoxychlor than the nonresistant strain, may be significant in that it indicates there may have been some selection by DDT for the false stable flies. The lack of a known susceptible strain of false stables flies made it impossible to substantiate this. Further study will be necessary to determine the causes for this retention of susceptibility. However, its solution may be of importance in shedding light on the development of resistance and or the probability of the development of resistance in various other species.

SUMMARY.—The life cycle of the false stable fly, *Muscina stabulans* (Fallén), from egg to egg required from 20 to 25 days in the laboratory at a temperature of 80.0° ± 2.5° F. and 60.0 ± 2.5 per cent relative humidity using a rearing method modified from the C.S.M.A. method for rearing the house fly, *Musca domestica* L.

The false stable fly was not found to be resistant to DDT, lindane, or methoxychlor in comparative tests with a nonresistant house fly strain from the laboratory and a resistant house fly strain from the same collection source.

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Effect of Time of Pollination by Honey Bees on Red Clover Seed Yields[1]

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In using bees for the pollination of medium red clover, the correct time to place colonies in the field is an important consideration. Recommendations often state that the bees should be moved in just as the clover begins to blossom, with the idea that they are then less likely to work other nectar sources. The influence of the timing on honey bee activity on the clover, and therefore on seed yields, has not been previously investigated experimentally. Many complicating factors affect the tendency of the bees to established their activities on the red clover bloom. This plant, as well as others in bloom nearby, may vary greatly in attractiveness to bees, even from day to day. Since the red clover may come into bloom before the beekeeper can remove the honey crop from other clovers, he is sometimes reluctant to move the bees into the field as early as is desired.

The time limitations for the pollination of the red clover flower also govern the time when the bees are required, if a maximum job of pollination is to be done. Observations at Columbus, Ohio, in 1949, 1950, and 1951, and in Delaware and Wood Counties, Ohio, in 1951 show that bees do not always begin pollinating activities in adequate numbers immediately after being moved into clover fields. Sometimes considerable delay occurs. As a consequence, important portions of the early bloom are not pollinated and seed yields are accordingly decreased. The reasons for the delay are not evident, because the bees seem to have little hesitancy or delay in beginning operations on other blossoms, such as alfalfa.

The progressive type of development of bloom in red clover has an important bearing on pollination requirements, since it extends the blossom period and spreads the pollination job of the bees. The flowers of the individual head develop progressively, and there is also a succession of heads on each plant. The first florets to open lie around the base of the new head, often on one side. At this time the head is small,

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[3] The author is grateful to B. A. App for assistance in the experimental work and its analysis.

but it continues to develop and expand in the center, throwing out a succession of new florets which open as they are produced, until the last florets open at the tip of the head. The usual total number of florets is about 100 or more. The period required for the head to come into full bloom may cover nearly a week after the first florets open, depending on temperature and other environmental factors. As the head approaches full development the stem often throws out another branch below it, on which develops a new head. The process may continue 3 or 4 weeks at Columbus, and sometimes as long as 6 weeks, as was the case in 1950, when frequent rains prolonged growth during the blossom period.

Westgate & Coe (1915) state that flowers of red clover wither shortly after fertilization takes place, whereas flowers of heads covered to exclude pollinators remained in full bloom 9 to 10 days. They place the time elapsing between pollination and fertilization at 18 to 50 hours. Present observations were confined to the progress of withering in relation to flower development. Slight changes in the appearance of the petals of florets pollinated by a bee may be detected within a few hours. In large cages with heavy honey bee populations florets were visited within a few hours after they opened, and they withered in less than 24 hours. In fact, the bees visited many florets before they were completely open. With the pollinators keeping pace with flower development, it often happens that the basal florets of the opening blossom head will wither before the apical florets have opened. All florets may be pollinated and may wither within 4 days from the time the first florets open. This situation, which indicates maximum pollination, is favorable for large seed yields under field conditions. Interruptions of honey bee activity by inclement weather would cause only small accumulations of young unfertilized flowers. Florets in cages from which bees were excluded remained fresh from 4 to 10 days. The clover within these cages maintained a beautiful appearance during the entire blossom period, owing to the great number of florets that remained fresh, in contrast with the clover to which the bees had access.

Data on the importance of pollination in various segments of the blossom period were obtained on experimental plots at Columbus in 1950. Pollination was provided by 4 colonies of bees per acre, which were moved into the clover field at the beginning of the blossom period. Instead of caging bees over the clover plots for definite periods, cages were used to exclude the bees during the period when no pollination was desired, and the cages were removed for the desired pollination period. Thus each plot received uniform open-field pollination for a specific period. The cages were made of eight-inch-mesh plastic screen covering a light wooden frame 3 by 3 by 3 feet. Some flowers within the cages touching the screen were visited and doubtless were pollinated by bumble bees outside.

Plots in a randomized block, replicated 4 times, were located in 6 by 6 foot areas, so that the cages would not constitute serious obstacles to pollinators working in adjacent plots. Sixteen cages served to control bee activity on the 32 plots, because for each plot covered to exclude bees for a definite period there was also a corresponding uncovered plot. The main blossom period covered 5 weeks, instead of the 4 anticipated when the experiment was planned. Consequently, it was necessary to include fifth-week pollination activity with that of the fourth week. The number of blossoms and seed yields in the fifth week, however, were relatively small and did not materially affect results.

Results of these experiments (Table 1) demonstrate that, for maximum seed yields, pollination should be provided over the entire blossom period. The loss of any segment of the blossom period may affect yields seriously. The importance of pollination in the early periods may be accentuated in seasons like 1949 and 1951, when blossom periods were shorter than in 1950, owing to dry weather.

Data on clover heads under observation each week in 4 replicated plots (Table 2) indicate that the larger heads develop in the first 3 weeks, furnishing the greatest potential yielding capacity in the early period. Furthermore, this period is also the time when the greatest number of heads are in bloom in the field.

SUMMARY.—The time to place bees in the field for maximum pollination service is governed by bee behavior and also by the requirements of the plant. Sometimes delays in obtaining pollination when

Table 1.—Influence of time and length of pollination period on seed yields in red clover, 1950.

POLLINATION PERIOD	SEED YIELD PER ACRE
	Bushels
None (caged entire period)	0.6
First week	1.5
First 2 weeks	3.9
First 3 weeks	8.0
Entire season	7.4
Last 4 weeks	6.6
Last 3 weeks	5.0
Last 2 weeks	2.3
Difference required for significance:	5%=1.8 bu. 1%=2.6 bu.

Table 2.—Size of red clover heads, and seed yields, 1950.

WEEK NO.	FLORETS PER HEAD, AVERAGE	SEEDS PER HEAD, AVERAGE	FLORETS WITH SEED
	Number	*Number*	*Per Cent*
1	115.1	80.5	70.0
2	118.2	76.2	64.4
3	107.1	90.5	84.4
4	92.0	73.7	80.1
5	74.4	55.3	74.3
Average	101.4	75.2	74.2

needed have adversely affected seed yields.

The progressive flowering characteristics of the red clover plant influence pollination requirements by spreading the pollination job of the bees over a period of 3 to 4 weeks, or longer.

With an adequate pollinator population the withering of florets, indicating pollinating activity, kept pace with flower development. In replicated plots on which the time that bees were permitted to pollinate the flowers was regulated by using cages, significant increases in seed yield followed increases in the length of the period the bees were permitted to visit the clover.

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Relative Toxicity to House Flies of Scabrin and Its Mixtures with Some Pyrethrum Synergists[1]

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The presence of insecticidal material in three American species of *Heliopsis*—*H. scabra* Dunal., *H. gracilis* Nutt., and *H. parvifolia* A. Gray—was recently demonstrated against house flies *Musca domestica* L. (Gersdorff & Mitlin 1950). Extractives of the roots of *H. scabra* were especially toxic. A toxic substance was isolated and shown to be the N-isobutylamide of an unsaturated 18-carbon straight-chain acid or a mixture of isomers (Jacobson 1951). The name "scabrin" was proposed for this substance. A summary of the available information on scabrin, as well as a pertinent description of *Heliopsis* species, has also been made (Roark 1951).

Kerosene sprays containing scabrin appear to be less stable than those containing pyrethrins; those at high concentrations, especially, lose toxicity after several days. However, the solubility of scabrin may be a factor. Further investigation is being made on this subject and also on the possible use of antioxidants in lengthening the life of such sprays. Pending this investigation, studies were undertaken with the now purified material to determine its toxicity to house flies in kerosene sprays in comparison with pyrethrins, and also to examine mixtures of scabrin and some of the pyrethrum synergists for possible synergistic action against the same insect.

MATERIALS.—Purified scabrin[2] was incorporated in refined kerosene sprays at concentrations selected in preliminary tests. Pyrethrum sprays were prepared

[1] Presented at the meeting of the Eastern Branch of the American Association of Economic Entomologists at New York, N. Y., November 15–16, 1951.

Furnished by M. Jacobson, Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

[2] "*DHS*."

Table 1.—Knockdown and mortality of house flies caused by space sprays containing scabrin and pyrethrins alone and scabrin in mixtures with pyrethrum synergists.

Material and Number of Replicates	Concentration Mg/Ml.		Knockdown, 25 Min.	Mortality, 1 Day
	Insecticide	Adjunct		
Series 1—Tests with Unixed Sprays				
Scabrin 8	4.0	—	100%	84.4%
	2.0	—	99.7	61.7
	1.0	—	98	25.4
	.5	—	88	7.1
Pyrethrins 8	8.0	—	100%	93.2%
	4.0	—	100	71.2
	2.0	—	100	53.2
	1.0	—	100	19.4
Series 2—Tests to Study Joint Action				
Scabrin plus—				
Sulfoxide 6	0.80	8.0	99.3%	95.2%
	.60	6.0	99.0	82.7
	.45	4.5	98	58.6
	.338	3.38	97	36.5
Synergist 264 6	0.80	8.0	98	26.5
	.60	6.0	97	24.9
	.45	4.5	95	6.4
Piperonyl butoxide 6	0.80	8.0	98.9	87.8
	.60	6.0	99.1	69.9
	.45	4.5	98	39.1
n-Propyl isome 6	0.80	8.0	98	52.3
	.60	6.0	96	32.1
	.45	4.5	92	17.1
Piperonyl cyclonene 6	0.80	8.0	99.7	65.6
	.60	6.0	99.1	40.8
	.45	4.5	98.6	25.8
D. H. S. Activator 6	0.80	40.0	97	13.0
	.60	30.0	97	7.7
	.45	22.5	92	5.7
"Benzyl propyl ether" 6	0.80	8.0	99.1	30.3
	.60	6.0	98.7	18.7
	.45	4.5	94	5.3
Scabrin 2	4.0	—	100%	87.3%
6	2.0	—	100	51.6
	1.50	—	99.8	32.2
	1.125	—	99.7	18.6
	0.844	—	98	9.8
Pyrethrins 6	8.0	—	100%	89.1%
	4.0	—	100	72.8
	2.0	—	100	51.9
	1.0	—	100	16.4
Series 3—Tests with mixed sprays 29 weeks old				
Scabrin plus—				
Sulfoxide 6	0.45	4.5	93%	69.1%
Piperonyl butoxide 6	0.60.	6.0	99	79.1
Scabrin (freshly prepared) 6	2.0	—	100	65.8
Pyrethrins 3	2.0	—	100	58.7

from an extract of pyrethrum flowers the total pyrethrins of which contained 54 per cent pyrethrin I and cinerin I.

The following pyrethrum synergists were used: Sulfoxide (*n*-octyl sulfoxide of isosafrole), synergist 264 (N-octyl bicycloheptene dicarboximide), piperonyl butoxide, *n*-propyl isome, piperonyl cyclonene, and an activator[3] (ethylene glycol ether of pinene). These were all technical materials. Another material that has shown some synergistic activity in pyrethrum mixtures (LaForge *et al.* 1947), the purified compound 3,4-methylenedioxybenzyl *n*-propyl ether, was also used. It is hereafter referred to as the benzyl propyl ether. Mixtures of scabrin and each of these adjuncts were prepared in refined kerosene at selected concentrations. With one exception 10 times as much adjunct as insecticide was used. In the sprays containing the activator 50 times as much adjunct as scabrin was used, the ratio recommended by the manufacturer for mixtures with pyrethrins.

Since one purpose of the tests was to select the most effective mixtures rather than to compare quantitatively all mixtures, the concentrations of the sprays were the same for all.

PROCEDURE.—The tests were made by the Campbell turntable method on adult, laboratory-reared house flies. Knockdown and mortality were determined in replicated tests, approximately 100 flies averaging 3 days in age being used in each test.

It had been found in previous tests that after several days there was separation of material, with accompanying loss of toxicity, in a spray containing 4 mg. of scabrin per milliliter. Inasmuch as a month or more would be required to complete the tests with the large number of sprays included in this study, one series of tests, sufficiently replicated, was made with scabrin and pyrethrum sprays within 3 days after they had been prepared.

In the tests on joint action, to avoid the danger of testing a deteriorated spray, scabrin was used at the 4-mg. concentration only in two tests made immediately after the sprays had been prepared. All populations of flies in this series were uniform in relative susceptibility so that the mortality given for this spray was comparable with the others. The other sprays were kept in the dark at room temperature when not in use, and there was no noticeable deterioration in them. Pyrethrum sprays were also included in this series for comparison with the sprays containing scabrin alone.

After these tests had been completed, it became evident that not only was mortality greatly augmented by addition of some of the adjuncts to scabrin sprays but also that the toxicity of the mixtures appeared to be stabilized. Therefore, to gain information on the maintenance of their toxicity, the two most effective

[3] D.H.S.

Table 2.—Relative toxicity to house flies of scabrin and pyrethrins at three mortality levels.

Material	Regression Coefficient (Probits per Unit Log Concentration)	LC 90 (Milligrams per Milliliter)	Ratio	LC 50 (Milligrams per Milliliter)	Ratio	LC 25 (Milligrams per Milliliter)	Ratio
Series 1:							
Scabrin	2.79±0.09	4.81±0.21	1.46±0.09	1.67±0.04	1.26±0.04	0.950±0.03	1.17±0.05
Pyrethrins	2.45±0.09	7.02±0.31	1.00	2.11±0.05	1.00	1.12 ±0.04	1.00
Series 2:							
Scabrin	3.64±0.13	4.41±0.16	1.74±0.11	1.96±0.03	1.14±0.04	1.28 ±0.02	0.91±0.04
Pyrethrins	2.40±0.09	7.67±0.38	1.00	2.24±0.06	1.00	1.17 ±0.05	1.00

mixtures, those containing sulfoxide and piperonyl butoxide, were retested 29 weeks after their preparation in comparison with a freshly prepared scabrin spray and the original pyrethrum spray.

MORTALITY AND KNOCKDOWN.—The results of the tests are assembled in table 1. During the month required for the tests in series 2 there was no apparent loss in toxicity in any of the sprays. The results in series 3 show that after 29 weeks the mixtures containing sulfoxide and piperonyl butoxide still maintained their high level of effectiveness in comparison with pyrethrins and a fresh sample of scabrin.

In all mixtures the knockdown of flies was of high order. Scabrin alone was nearly as effective in this respect as pyrethrins.

EVALUATION OF RELATIVE TOXICITY.—Certain approximate relationships are apparent from the mortality data. However, to put them on a more quantitative basis the data, except those for the mixtures of scabrin with the activator, were subjected to probit analysis as described by Finney (1947). The equations for the 10 regression lines, given below, show the relationship between the probits and logarithms of the concentrations in milligrams per deciliter. Those for the mixtures are based on the expression of concentration in terms of scabrin content only. As may be seen, the equations are not generalized but are those of the individually fitted lines.

Pyrethrins, series 1	$Y = -0.695 + 2.451\ X$
Scabrin, series 1	$Y = -1.213 + 2.795\ X$
Pyrethrins, series 2	$Y = -0.628 + 2.395\ X$
Scabrin, series 2	$Y = -3.354 + 3.644\ X$
Scabrin mixture containing—	
Sulfoxide	$Y = -3.520 + 5.322\ X$
Synergist 264	$Y = -2.050 + 3.437\ X$
Piperonyl butoxide	$Y = -4.891 + 5.829\ X$
n-Propy isome	$Y = -2.644 + 4.044\ X$
Piperonyl cyclonene	$Y = -2.682 + 4.229\ X$
"Benzyl propyl ether"	$Y = -3.704 + 4.330\ X$

Estimations from the analysis of the data are given in tables 2 and 3. Scabrin and pyrethrins do not give parallel lines, for their regression coefficients are significantly different in each comparison (Table 2). Therefore, comparisons of the two materials were made at three mortality levels. Scabrin was as toxic as pyrethrins at the 25 per cent level, 1.2 as toxic at the 50 per cent level, and 1.6 as toxic at the 90 per cent level. The mixtures containing the adjuncts most effective in augmenting mortality, sulfoxide and piperonyl butoxide, gave regression coefficients that did not differ significantly from each other but did differ from those of the other scabrin-

Table 3.—Data calculated for determining the comparative effect of pyrethrum synergists in scabrin sprays.

Material	Regression Coefficient (Probits per Unit Log Concentration)	LC 50 (Milligrams per Milliliter)		Relative Standard Error of Concentration (Per Cent)	Ratio of Toxicity on Basis of—		Log of Ratio of Equivalents	Minimum Log Required to Show Synergism
		Original Basis	Scabrin Equivalent		Scabrin Content	Scabrin Equivalent		
Scabrin	3.64±0.13	1.96	1.96	1.75	1.00	1.00		
		1.28[1]	1.28[1]	1.89[1]	1.00	1.00		
Scabrin plus—								
Sulfoxide	5.32±0.24	0.399+3.99	.463	1.47	4.91	4.23	0.626	0.020
Syngergist 264	3.44±0.31	.716+7.16[1]	.881[1]	2.48[1]	1.79	1.45	.161	.027
Piperonyl butoxide	5.83±0.33	.498+4.98	.617	1.51	3.94	3.18	.502	.020
n-Propyl isome	4.04±0.32	.777+7.77	.963	2.52	2.52	2.04	.310	.027
Piperonyl cyclonene	4.23±0.31	.655+6.55	.793	1.78	2.99	2.47	.393	.022
"Benzyl propyl ether"	4.33±0.31	.715+7.15[1]	.779[1]	2.00[1]	1.79	1.64	.215	.024

[1] Based on 25 per cent mortality.

containing sprays (Table 3). The latter did not differ significantly within the group. Parallel lines for the scabrin-containing sprays in series 2 could therefore have been fitted in two groups. However, the information obtained from the individually fitted lines as given in table 3 sufficed for this study.

The activator apparently had no effect in increasing the toxicity of scabrin sprays, for the mortality results in table 1 were about as would be expected from scabrin alone at similar concentrations. Therefore, this material was excluded from further study. The sprays containing synergist 264 and the benzyl propyl ether caused mortalities lower than 50 per cent but higher than those to be expected from scabrin alone. Therefore, these sprays were given further study, but comparison with scabrin was made at the 25 per cent mortality level. The other mixtures were compared with scabrin at the 50 per cent level.

To demonstrate synergism and measure its intensity when the adjuncts themselves are toxic, the insecticide equivalents of the mixtures must be determined. It was not possible to test sprays containing the adjuncts alone for direct comparison with scabrin. However, scabrin equivalents could be estimated from values obtained in comparison with pyrethrins (Gersdorff *et al.* 1951) and the toxicity of scabrin in relation to pyrethrins estimated at the 50- and 25-per cent levels of mortality. The value chosen to express the relative toxicity of scabrin at each level was the weighted mean of the ratios obtained in the two comparisons in table 2. The values obtained for the scabrin equivalents of the adjuncts are shown in table 4. The scabrin equivalent of any mixture was then calculated as the sum of the scabrin equivalent of the amount of the adjunct in the mixture and the actual amount of scabrin. The relative toxicities determined on this basis and also on the basis of actual scabrin content are given in table 3.

To show an increase in toxicity of the mixtures over that expected from the scabrin equivalents and thus to demonstrate synergism, it was necessary to determine the standard errors. This was done according to the maximum likelihood method described by Finney (1947).

Table 4.—Toxicity of the adjuncts relative to scabrin as calculated from their toxicity relative to pyrethrins.

Material	Ratio to Pyrethrins at—		Ratio to Scabrin at—	
	LC 50	LC 25	LC 50	LC 25
Pyrethrins	1.00	1.00	0.83	0.96
Scabrin	1.21	1.06	1.00	1.00
Sulfoxide	.019	—	.016	—
Synergist 264	—	.024[1]	—	.023
Piperonyl butoxide	.029[1]	—	.024	—
n-Propyl isome	.029[1]	—	.024	—
Piperonyl cyclonene	.025	—	.021	—
"Benzyl propyl ether"	—	.010	—	.009

[1] Given in Gersdorff *et al.* 1951, or estimated from data therein.

The standard errors are reported in table 3 as relative standard errors. The logarithms of the ratios of equivalents and the minimum logarithms required to demonstrate synergism are given, since tests of significance are properly made on the log concentration scale. As shown in these two columns, such tests produce decided evidence of synergism in all the mixtures in table 3.

The intensity of synergism was greatest in the mixture containing sulfoxide, and successively lower for piperonyl butoxide, piperonyl cyclonene, *n*-propyl isome, the benzyl propyl ether, and synergist 264.

SUMMARY.—The relative toxicity of scabrin in simple sprays and in mixed sprays with some pyrethrum synergists was determined against the house fly, *Musca domestica* L., by the turntable method.

The toxicity of scabrin increased more rapidly with increase in concentration than did that of pyrethrins; the two toxicants were about equally toxic at the 25 per cent mortality level, but at the 90 per cent mortality level scabrin was about 1.6 as toxic as pyrethrins.

The joint action in mixtures containing 10 times as much adjunct as scabrin was of the synergistic type with the following materials, given in decreasing order of intensity of synergism: Sulfoxide, piperonyl butoxide, piperonyl cyclonene, *n*-propyl . isome, 3,4-methylenedioxybenzyl *n*-propyl ether, and synergist 264. The mixture containing sulfoxide was 4.2 and the mixture containing synergist 264 was 1.5 as toxic as scabrin alone. On the basis of actual scabrin content these two mixtures were 4.9 and 1.8, respectively, as toxic as scabrin alone.

No synergism was demonstrated in a

mixture containing 50 times as much activator as scabrin.

The mixtures containing sulfoxide and piperonyl butoxide still maintained their high level of effectiveness after 29 weeks.

In all mixtures the knockdown of flies was of high order. Scabrin alone was nearly as effective in this respect as pyrethrins.

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Spider Mite Control on Cotton[1]

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Spider mites have over a long period of time been considered a pest of cotton in some areas of the Cotton Belt, but not until the organic insecticides came into general use did these pests develop to damaging numbers in this State. It was soon found that mites increased following the use of organic insecticidal dusts, especially in cases where sulphur was not added to the dust mixtures. With the addition of at least 40 per cent sulphur to the insecticidal dusts, the mite infestations seldom developed to injurious numbers. Since it is possible to apply these organic compounds as spray emulsions and effect control of pests, a special effort has been made to find acaricides suitable for mixture with sprays.

Iglinsky & Gaines (1949) found parathion and sulphur dusts effective for the control of the spider mite, *Septanychus texazona* McG. on cotton and peanuts. This species of mite is prevalent on cotton in this area of the State.

For the past several years, experiments have been conducted in the College Station Laboratory in an effort to evaluate a number of sulphur and phosphorus compounds suitable for mixing with emulsion sprays in spider mite control. The results of these tests have been reported by Magee & Gaines (1950), Gaines *et al.* (1950, 1951), Ivy *et al.* (1950) and Mistric & Rainwater (1952). Several phosphorus and sulphur compounds were found to be effective in the laboratory. The most promising of these materials were used in field tests during 1951 and the results of these tests are herein reported.

LABORATORY TESTS.—It has been established that the two-spotted mite *Tetranychus bimaculatus* Harvey occurs in the Western part of the State and it may also occur in mixed populations with *S. texazona* McG. Since the 2 species occur separately and at times together, it was deemed advisable to compare the acaricides for the control of both species. Pure cultues of each of the 2 species were reared in the laboratory on seedling cotton. The methods used for growing the cultures and conducting the tests have been described in the papers referred to above. Approximately 25 mites were transferred to clean cotton seedlings 24 hours preceding the application of acaricides. Six replicate plants were treated with each dosage of material and from 4 to 8 dosages were required, involving 1500 or more mites, to establish the dosage-mortality relationships shown in table 1. The numbers of live and dead mites were recorded daily for 5 consecutive days following treatment. The percentages of mortality were calculated by Abbott's formula.

The following materials were used in tests against both species of spider mites:

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aramite,[1] ovotran,[2] sulphenone,[3] genite-923,[4] EPN and parathion sprays and sulphur dust. Aramite was more toxic to the mites than any of the other sulphur compounds. Each of the sulphur compounds proved more toxic to *Septanychus texazona* McG. than to *Tetranychus bimaculatus* Harvey while the phosphorus compounds were more nearly equal in effectiveness against both species. Sulphur dust used in excessive quantities failed to control *T. bimaculatus* Harvey.

GREENHOUSE TESTS.—The residual tests were conducted in the greenhouse at average daily temperatures ranging from 78.9° to 102.6° F. and average relative humidities ranging from 46.2 to 93.9 per cent. The sprays were applied to potted cotton plants with the spraying apparatus described in literature cited above. A pressure of 60 pounds was used and each hollow cone nozzle delivered approximately 2.5 gallons of spray per acre. The spray was applied as the plants passed under the sprayer at a constant speed. Cotton plants heavily infested with spider mites were treated and at the same time were kept in the greenhouse in close proximity to heavily infested plants, affording the treated plants the opportunity of being reinfested throughout the test period. Eight potted plants were treated with each dosage of each material and the mite counts were made on 2 designated leaves on each plant. The results of these tests are shown in table 2.

Systox, a systemic acaricide, and parathion were used in these greenhouse tests. The residual toxicity of parathion was approximately 7 days as compared with 15 days for systox applied at .25 pound per acre and 20 to 25 days for systox applied at 0.5 pound per acre. The increased dosage dosage extended the residual toxicity of systox. Systox was also found to possess excellent contact qualities at these dosages.

OVICIDE TESTS.—The results of residual ovicide tests reported by Armstrong (1950) indicated that ovotran was effective against *Tetranychus bimaculatus* eggs. In these tests, the plants were sprayed before the female mites deposited their eggs and a high pressure and high volume fine spray was used to thoroughly cover both sides of the leaves to the point of run-off. In the tests herein reported, a low pressure and low volume spray was applied to the plants after the eggs had been deposited to simulate sprays generally used to control cotton insects.

Approximately five females of each species of mites were placed on each seedling leaf and allowed to remain for a period of 24 hours. The females were carefully removed to avoid disturbing the eggs as much as possible. The number of eggs deposited on the plants by the females during this 24-hour period are shown in table 3. The number of eggs and live larvae were recorded daily during a 5-day period following the application of acaracide. The percentages of hatch and larval mortality were calculated by Abbott's formula using data recorded on the fifth day.

The sprays were applied to the plants upon which the eggs were deposited from the top of a spraying tower through a

[1] 2-(p-tert-Butylphenoxy)-1-methylethyl 2 chloroethyl sulfite.
[2] p-chlorophenyl p-chlorobenzene sulfonate.
[3] p-chlorophenyl phenyl sulfone.
[4] 2, 4 dichlorophenyl ester benzene sulfonic acid.

Table 1.—The dosage-mortality relationship of the materials indicated in laboratory tests at College Station, Texas.

Treatment	*Septanychus texazona* McG. Amount of Toxicant[1] to Give—			*Tetranychus bimaculatus* Harvey. Amount of Toxicant[1] to Give—		
	50% Control	90% Control	Slope of Line	50% Control	90% Control	Slope of Line
Aramite	.022	.308	1.123	.273	.725	3.025
Ovotran	.415	1.950	1.907	.554	3.289	1.659
Sulphenone	.212	1.266	1.836	2.033	6.210	2.645
Genite-923	1.108	3.590	2.528	2.455	16.070	1.588
EPN	.119	.324	2.941	.154	.368	2.386
Parathion	.024	.052	3.839	.032	.188	1.668
Sulphur (dust)	10.76	24.10	.949		[2]	

[1] Pounds active ingredients per acre.
[2] Excessive amounts of sulphur dust failed to give 90% mortality of *T. bimaculatus* Harvey.

Table 2.—Comparative effectiveness of compounds indicated against spider mite, *Septanychus texazona* McG. in greenhouse test at College Station.

Compound	Dosage[1]	Per Cent Mortality on Indicated Days After Application					
		1	5	10	15	20	30
Parathion	.06	93.2	99.4	79.1	0		
Systox	.25	99.6	99.8	100.0	94.4	[2]	
	.50	100	100	100	100	100	[2]

[1] Pounds active ingredients per acre.
[2] Mites defoliated the untreated plants making it impossible to calculate the percentage mortality. On the 20th day following the dosage of 0.25 pound systox per acre, 154 mites were found on 16 leaves. On the 30th day following the dosage of 0.50 pound systox per acre, 102 mites were found on 16 leaves.

solid cone nozzle, delivering about 8 gallons of spray per acre.

The following materials were used in these ovicide tests: aramite, ovotran, sulphenone and genite-923. None of these acaricides applied as coarse sprays and at a low volume were effective as ovicides. Sulphenone and ovotran killed about one-half of the larvae hatching from the eggs on the fourth and fifth day after the application.

FIELD TESTS.—In a large area of the state, the mite population increased to injurious numbers on cotton during the growing season of 1951. These damaging mite infestations developed as a result of the destruction of the natural enemies by early applications of organic insecticides and also because of favorable weather conditions for mite development. Thus an opportunity was afforded for evaluating a number of acaricides for mite control. Samples of mites collected from several fields in which tests were conducted were identified by E. A. McGregor as *Septanychus texazona* McG. The tests herein reported were conducted in the vicinity of College Station.

Spray emulsions were applied either by airplanes or by power sprayers. The planes

Table 3.—Results of ovicide tests using acaracides as indicated in laboratory experiments at College Station, Texas.

Treatment	Dose[1]	Initial Count Eggs	Eggs Hatched	Mortality of Larvae
		T. bimaculatus Harvey		
Aramite	.30	94	100.0%	0.0%
Ovotran	2.00	126	100.0	8.6
Sulphenone	2.00	83	97.6	0.0
Genite-923	2.00	107	99.1	0.0
		S. texazona McG.		
Aramite	.30	177	85.9	6.6
Ovotran	2.00	181	79.6	56.8
Sulphenone	2.00	188	89.4	48.1
Genite-923	2.00	246	87.8	13.8

[1] Pounds active ingredients per acre.

Table 4.—The percentage reduction of mites following the use of acaricides as indicated in field tests at College Station, Texas.

Treatment	Method of Application	Dosage[1]	Initial Infestation[2]	Per Cent Reduction on Days as Indicated After Application									
				1	2	3	4	5	6	7	8	9	10
Aramite	Spray	.38	344		90.7			69.2		36.6	16.9	0.0	
	Spray	.42	534		46.1		96.8			95.7		94.2	
	Spray	.54	708		99.9	99.5	99.2		100.0		99.7		
	Spray (Plane)	.50	741	71.2			99.6		98.8		92.7		82.3
	Dust (Plane)	.36	488		98.6		99.3		99.1				40.6
	Dust	.36	475		64.8		94.9			90.7		93.7	
Ovotran	Spray	2.03	484		65.9		80.0		82.8		89.1		
	Spray	2.28	420		96.4			90.2		79.3	77.4	67.8	
	Spray	2.91	304		96.7			97.4		83.6			
	Dust	1.50	347		96.2			81.0		63.1	63.7	37.5	
	Dust	2.40	510		61.4		61.0		66.5		80.8		
Sulphenone	Spray	1.29	843		72.1	79.4			90.6			70.7	
	Spray	1.60	1283		80.2			90.4					
	Spray	2.85	272		98.2			99.6		100.0			
	Spray (Plane)	1.25	366		26.5		60.9		58.5		19.4		
	Dust	1.90	410		80.7		82.7			70.5		72.3	
Genite-923	Spray	1.87	809		63.9		81.9						
	Spray	2.01	273		91.6		94.2			63.7			
	Spray	2.25	289		97.9		97.9			98.6			
TEPP	Spray	.18	876		91.9			47.0					
	Spray (Plane)	.25	1273	100.0	82.5		66.0		46.6				
Parathion	Spray	.29	402		99.0			99.8		97.8	88.3	66.9	
	Dust	.24	502		100.0		99.0			93.6		93.2	
TM-4049	Spray	.20	459		94.1		84.7			57.7			
	Dust	.11	839		98.6		93.2		86.2		77.6		
	Dust	.27	380		11.8		19.7			44.2			
EPN	Spray	.21	483		95.4			85.5		40.4	18.4	40.0	
	Spray	.26	399		99.7			99.0		88.5	65.4	47.4	
	Spray	.25	327		92.7		97.9			86.5		91.6	
Sulphur	Dust	15.00	806		93.3		93.2		97.3		95.4		
	Dust	20.00	311		93.2		92.0			84.2		71.1	

[1] Pounds active ingredients per acre.
[2] Number of mites on 25 leaves.

covered swaths of approximately 36 feet, delivering 2 gallons of spray per acre while the power sprayers delivered about 7.5 gallons of spray per acre through three cone nozzles per row. The dusts were applied with either planes or hand dusters. The plots varied in size from one-tenth acre to 10 or more acres. A number of different dosages were applied in an effort to determine which was the most effective. The dosages of each acaricide which gave adequate control of the mites are shown in table 4. The materials used in the tests were: aramite, ovotran, sulphenone, genite, TEPP, parathion, TM-4049,[1] EPN and sulphur dust.

The population of spider mites was determined by counting the mites on twenty-five tagged leaves in each plat. The leaves were tagged, in order that the same leaves could be examined on each date. This method eliminated as much variation in the population data as possible. The reduction in mite populations resulting from the various dosages of the acaricides is shown in table 4.

Of the sulphur compounds, aramite proved most toxic to spider mites. About 0.4 pound per acre of aramite gave control of mites comparable to 2 pounds of ovotran, sulphenone, genite-923 or 15 pounds of sulphur dust. These sulphur compounds appeared to be effective for a period of 6 or 7 days. None of the materials gave complete or "knock out" control. The residual toxicity was not sufficiently prolonged to kill all the larvae hatching from the eggs. The phosphorus compounds, parathion, TM-4049, TEPP and EPN gave effective control at about 0.25 pound per acre. The residual toxicity of TEPP was inferior to that of the other compounds and several applications were necessary to effect control of mites.

The acaricides proved effective when applied by either ground machinery or airplanes in the form of emulsion sprays or dusts.

Octamethyl pyrophosphoramide and systox, systemic insecticides, were applied to 5-acre cuts of cotton with a tractor sprayer. These materials applied at 0.5 pound per acre proved effective in preventing mites from developing for a period of about 4 weeks. Systox at this high dosage also proved to be an excellent contact poison.

SUMMARY.—The sulphur compounds, aramite, ovotran, sulphenone and genite-923 and sulphur dust proved more toxic to *Septanychus texazona* McG. than to *Tetranychus bimaculatus* Har. while the phosphorus compounds, parathion and EPN were more nearly equal in effectiveness against both species.

In residual tests conducted in the greenhouse and in the field, systox proved to be an excellent contact poison and controlled mites for a period of 3 or 4 weeks by being translocated by the plants. Octamethyl pyrophosphoramide also proved effective for a period of 3 or 4 weeks in the field.

Ovotran, aramite, sulphenone, and genite-923 were ineffective as ovicides when applied as coarse low volume sprays. Ovotran and sulphenone killed about one-half of the larvae hatching from the eggs on the 4th and 5th day after the application of the acaricide.

Approximately 0.4 pound per acre of aramite gave control of mites in the field comparable to that of 2 pounds of ovotran, sulphenone, genite-923 and 15 pounds of sulphur dust. The phosphorus compounds, parathion, TM-4049, TEPP and EPN gave effective control at about 0.25 pound per acre.

Systox and octamethyl pyrophosphoramide proved effective in mite control for a period of 3 to 4 weeks.

[1] S-(1,2-dicarbethoxyethyl) 0,0dimethyl dithiophosphate.

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Incidence and Habits of Tabanidae at Summer Lake, Oregon[1]

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Numerous species of Tabanidae are serious pests of livestock and man. These insects not only suck the blood and torment livestock but transmit tularemia, a bacterial disease of man and of some rodents (Francis & Mayme 1921). In Oregon and other places in the West various species of Tabanidae are of economic importance in small areas, usually in the vicinity of marshes, shallow lakes, and swampy areas along slow moving streams. Gjullin & Mote (1945) and Roth & Lindquist (1948) have reported on the deer fly problem at Summer Lake, Oregon, an area which is abundantly populated with Tabanidae. Additional information on the abundance, distribution, and biting habits of two common deer flies of the genus *Chrysops* and 3 horse flies of the genus *Tabanus* found at this lake is presented herein.

Observations on the Biting Habits of Tabanidae.—All the species found in this area annoy all classes of livestock, but some differences have been noted in their persistence and site of attack. They have been observed biting cattle, horses, hogs, sheep (on the face), and man. The various breeds of cattle appear to be about equally susceptible.

Chrysops discalis Will. is the most abundant species in the Summer Lake Valley, but is found chiefly in the areas near the main lake. It will bite the livestock at any place on the body, but seems to prefer the neck and head. It has been seen biting wild rabbits on the ears. It is less persistent than other species and will fly when the animal moves. These flies attack man freely and will bite through light-weight jackets.

Chrysops bishoppi Brennan is not nearly so abundant as *C. discalis*, but is a persistent biter and will attack any place on the animal. The pest is most common in the foothill area. It seldom attacks man.

Tabanus sonomensis Osten Sacken is a large species, present in great numbers in irrigated pastures. It is a persistent and ferocious biter on the back, sides, and face of the animal. It also attacks man with equal ferocity.

Tabanus productus Hine has been observed biting and annoying livestock. This small horse fly prefers to attack animals on the legs and under the belly. It does not usually attempt to bite man except below the knees. This fly has frequently been seen flying just above the grass near grazing animals, whereas other tabanids fly at a higher altitude.

Tabanus punctifer Osten Sacken is the largest species in the area. It is fairly abundant, and attacks livestock, preferably on the back.

Incidence on Cattle—Numerous counts have been made to obtain information on the numbers of the various species flying around, landing on, or biting domestic animals. All counts were made on one side of the animal. It is easy to know when a tabanid is about to bite, because it tilts its head forward slightly. However, counting tabanids on unrestrained cattle on pasture is difficult, as animals pestered with the flies fight them constantly by kicking, pawing the ground, switching their tails, and twitching their muscles. A sudden increase in wind velocity or fleeting clouds obscuring the sun will abruptly reduce fly activity. Tabanids do not as a rule engorge on the first landing, but on being disturbed fly off, only to return again and again until they obtain a full blood meal. A fly may make 20 or more attempts, actually piercing the skin with its proboscis, during a short time. The mere momentary landing on the hair causes the animal to react violently by swinging its head. Cattle appear to be much more sensitive to tabanids than to horn flies; several hundred horn flies cause less agitation than do a dozen or so tabanids.

A counting period must be chosen that includes the initial landing and also the repeated returns to the animal. During a 15-second counting period used in 1948,

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Table 1.—Number of Tabanidae counted on one side of dairy cows.

LOCALITY	DATES OF OBSERVATION	NUMBER OF ANIMALS EXAMINED	LENGTH OF COUNTS	DEER FLIES	HORSE FLIES
Grizel ranch	July 10 to Aug. 13, 1948	89	15 sec.	7	4
	June 15–29, 1951	68	2 min.	7	40
Grave-Harris ranch	July 19–24, 1951	17	2 min.	13	36

an average of seven deer flies and four horse flies were recorded on the animal (Table 1). Two-minute counts in the same general area in 1951 showed three to six times as many horse flies as deer flies.

Table 2 gives the records taken in 1950 in which the species of Tabanidae were separated. The first records are totals of 10 separate 1-second counts per animal made in 1 minute. Tabanids were not so abundant during the second series of counts made in 2 minutes.

In several observations the number of *Chrysops discalis* flies that were biting and the number resting on calves over a 2-minute period were recorded. At the same time the aerial population of the insects was sampled with an insect net swung over the head 70 times while walking a distance of 200 feet near (50 feet) where the calves were tethered. These records were made on an alkaline flat near the lake during an extremely high fly incidence. Table 3 shows an average of approximately 10 deer flies landing on an animal in a day to 1 biting or attempting to bite. About as many flies were on the animals as were captured in the insect net.

The biting and resting of tabanids were further recorded on dairy cattle grazing in irrigated patures (Table 4). In10-second counts more *Chrysops discalis* were resting on the animals than were biting. However, the ratio of biting to resting was greater with *Tabanus sonomensis* than with C. *discalis*.

An attempt was made to capture in traps all the flies attracted to animals. A large screen cage was set up on an alkali flat at Hunters Point. The cage was open at the bottom and set up on legs 1 foot high, so that flies entered at the bottom. A calf was penned inside the cage. Incidence of tabanids was not high during these observations for a maximum of 400 *C. discalis* and 27 *Tabanus* spp. were caught in an hour.

Small screen-wire traps enclosing a domestic rabbit as an attractant were tried in many tests. The results were disappointing in that few flies were caught. A maximum of 12 *C. discalis* were trapped after 5 hours' exposures in places where the incidence of tabanids was high.

INCIDENCE AS DETERMINED BY AERIAL TRAP.—A rotating trap similar to that described by Chamberlin & Lawson (1940) was used to sample the aerial tabanid population in 1949 and 1951. This trap had two nets each with a diameter of 19.15 inches (2.8 square feet) attached to a 6-foot boom which revolved by means of a set of reduction gears and a gasoline motor. The nets were operated 1.5 feet off of the ground at a rate of 50 to 55 revolutions per minute. Approximately 496,000 cubic feet of air were sampled per hour.

With this type of trap the air could be sampled for tabanids without attractants such as animals or artificial baits. However, the movement probably drew some insects to the nets, since it has been ob-

Table 2.—Number of Tabanidae counted on one side of dairy calves, 1950.

LOCALITY	DATES OF OBSERVATION	NUMBER OF ANIMALS EXAMINED	LENGTH OF COUNTS	AVERAGE COUNT PER ANIMAL		
				C. discalis	*T. productus*	*T. sonomensis*
Hunters Point	July 13–26	13	10 sec.	40	20	9
Grizel ranch	July 10–17	11	10 sec.	30	30	50
Hunters Point	Aug. 1–3	3	2 min.	7	4	7
Grizel ranch	Aug. 9–11	9	2 min.	2	.04	4

Table 3.—Number of *Chrysops discalis* obtained over a 2-minute period on calves and in the air 50 feet from them. 1950.

Time	On Animals		Captured with Insect Net
	Biting	Resting	
June 22— 9 A.M.	0	10	2
10	0	4	21
11	0	4	20
12 NOON	8	60	82
1 P.M.	4	6	44
2	1	40	55
3	5	110	17
4	2	32	20
Average	2.5	33	33
June 25— 9 A.M.	0	0	0
10	4	2	14
11	5	32	54
12 NOON	6	38	71
1 P.M.	5	107	96
Average	4.0	36	47
June 26— 9 A.M.	0	0	1
10	1	24	34
11	2	52	18
12 NOON	6	101	67
1 P.M.	2	34	28
2	4	43	1
3	7	42	86
4	11	61	21
Average	4.1	42	32
June 29— 9 A.M.	6	29	49
10	2	72	56
11	8	83	57
12 NOON	10	46	38
1 P.M.	2	54	22
2	2	29	38
3	3	23	17
Average	4.7	48	40
July 7—10 A.M.	3	18	63
11	4	14	44
12 NOON	9	32	41
1 P.M.	5	6	56
Average	5.2	17	51

served a moving automobile or person attracts some species. The collection very likely represents a sample of the insects flying only in the immediate vicinity of the trap. Apparently these insects are on the wing much of the time.

In 1949 the trap was operated at Hunters Point on a sparsely grassed spit extending out towards the soft alkali mud flats within 100 feet of the lake. It was typical of thousands of acres of wild undeveloped area along the shore line of the shallow lake. In 1951 the trap was

Table 4.—Number of Tabanidae seen biting and resting on dairy cattle in a pasture during 10 seconds. 1950.

Date	*Chrysops discalis*		*Tabanus productus*		*Tabanus sonomensis*	
	B*	R	B	R	B	R
July						
12	1	17	0	0	1	34
	1	18	1	5	1	19
	3	26	0	0	2	19
14	1	12	0	2	0	19
15	1	13	0	2	1	20
	0	8	0	1	0	32
	0	10	0	25	0	28
	3	26	2	45	6	48
Average	1.2	16	0.4	10	1.4	27

* "B"—Biting; "R"—Resting.

used in irrigated pastures about 2 miles distant. Cattle grazing within 500 feet of the trap were severely attacked by tabanids. The insects were removed from the nets each hour during the day. Table 6 shows the average numbers of tabanids caught per hour over 4-hour morning and afternoon runs at the two locations. Both sexes of *Chrysops discalis* were taken, but only females of three other species.

A consistently larger number of males of *Chrysops discalis* were caught in the morning than in the afternoon, but in a few runs after 5 o'clock in the afternoon the number of males increased again. The males seemed to be more active during the cooler parts of the day. The number of females caught did not show a consistent relationship with the temperature or time of day. Wind and clouds also influence the activity of tabanids. Fewer *C. discalis* were caught in the irrigated pasture type of habitat than on the alkali flats, but more *Tabanus sonomensis* were taken in

Table 5.—Number of Tabanidae caught per hour in a large screen trap baited with a Hereford calf, Hunters Point, 1948. Exposure time ranged from 1 to 5 hours.

Date	Temperature ° F.	*Chrysops discalis*	*Tabanus* spp.
July			
12	74	87	27
26	87	400	22
28	69	30	5
Aug.			
5	78	17	5
7	78	24	8
13	80	21	5
17	72	10	3
18	70	6	1

Table 6.—Average number of Tabanidae caught per hour in a rotating trap run 4 hours in the morning and in the afternoon. Trap on Hunters Point except as indicated.

Date and Time	Mean Temperature, °F.	*C. discalis*		*Tabanus*		*Atylotus incisuralis*
		Males	Females	*sonomensis*	*productus*	
1949						
June 27						
A.M.	—	40	120	14	2	7
P.M.	—	5	523	8	2	14
July 21						
A.M.	64	42	340	4	7	2
P.M.	76	20	223	2	12	3
July 22						
A.M.	64	49	318	2	7	3
P.M.	74	14	128	2	4	2
July 25						
A.M.	61	38	64	4	3	1
P.M.	73	8	141	2	2	1
1951						
Aug. 1						
A.M.	74	12	83	5	5	2
P.M.	87	5	107	2	8	2
July 26						
A.M.	70	7	34	37	32	1
P.M.	84	2	27	30	38	2
July 27[1]						
A.M.	72	17	60	25	7	1
P.M.	88	7	66	44	33	1

[1] Irrigated pasture.

Table 7.—Average number of Tabanidae caught per hour of operation in a rotating trap set in an irrigated pasture except as indicated. 1951. Traps operated both A.M. and P.M. unless otherwise indicated.

Date	Daily Temperature Range, °F.	*Chrysops*		*Tabanus*		*Atylotus incisuralis*
		discalis	*bishoppi*	*sonomensis*	*productus*	
June 19	43–84	12	6	15	0.5	3
20	47–84	9	8	15	0.3	2
26	49–84	11	19	84	5	4
27	48–85	8	24	109	7	3
28[1]	48–87	15	11	124	4	1
July 6[1]	43–80	1	0.2	74	3	1
11[1]	46–82	8	2	97	15	3
12[1]	54–93	6	4	48	21	1
16	55–93	6	3	45	30	2
17[2]	57–95	3	3	48	36	0
18[1]	57–95	6	1	64	21	2
20[1]	45–89	3	0.1	36	9	1
24[1]	55–92	4	1	42	12	1
26	55–93	39	1	31	37	1
27	53–92	64	0.5	29	26	0.5
31[2]	57–97	5	1	97	60	2
Aug. 2	56–93	51	0	123	92	0.2
3	56–90	46	0.3	84	96	0.2
4[1]	51–89	12	0	73	21	1
6[1]	55–87	31	0.4	52	24	0
7[1]	52–86	14	0	62	18	0
8	44–82	14	0	51	11	0
23	44–77	2	0	3	0	0
24	37–80	3	0	31	0.2	0
June 22[3]	43–81	190	6	26	0	19
23[3]	44–82	333	4	20	0.5	18
Aug. 1[3]	57–95	131	0	4	7	2

[1] A.M.
[2] P.M.
[3] Alkali flat near lake.

irrigated pastures than on the alkali flats. The other species of tabanids did not show a consistent period of activity.

The catches obtained from a trap operating intermittently in 1951 are given in table 7. The length of the runs ranged from 2 to 12 hours, and all except three of them were made in an irrigated pasture. In this pasture *Tabanus sonomensis* was the most numerous and *T. productus* was second. *Chrysops discalis* was most numerous at Hunters Point on June 22 and 23, while *T. sonomensis* was the dominant species in the pasture on June 26, 27, 28. The greater prevalence of *C. discalis* near the lake has been observed at other times.

Six per cent of *Chrysops discalis* taken at Hunters Point and 12 per cent of those caught in the irrigated pasture were males. Only five males of *T. sonomensis* and eight of *Atylotus incisuralis* (MacQuart) were caught in the trap, whereas 6 per cent of the total *T. productus* were males.

Although *Tabanus punctifer* is fairly abundant on livestock, only 10 specimens were taken in the trap during the entire season. This large species may fly too rapidly to get caught in the swinging nets.

Egg Development of Flies Captured in Various Situations—Female *Chrysops discalis* were captured in various situations and examined under a binocular microscope to determine the development of their eggs. Of the flies caught over grass near an alkali flat, only 1 per cent contained large mature and 83 per cent contained small to medium-sized immature eggs (Table 8). Of the flies caught on adhesive-treated stakes set on the shoreline 98 per cent contained mature eggs, which is to be expected since they seek objects in or near water on which to oviposit. Only a small percentage of the flies captured in the act of biting animals

Table 8.—Development of eggs dissected from *Chrysops discalis*. June 15–24, 1949.

Place of Collection	Total Number Dissected	Per Cent of Flies Containing—			
		Observable Eggs	Small Round Eggs	Medium Oval Eggs	Large White Mature Eggs
Netted over grass	100	16	42	41	1
Attempting to bite animals	40	2.5	7.5	82.5	7.5
From adhesive-treated stakes	100	—	1	1	98

contained mature eggs, an indication that blood meals are necessary for the development of the egg or that the egg had not had time to develop.

Since eggs of *Tabanus sonomensis* have not been found in nature, a large number of females were captured and examined to determine what the eggs might look like and their stage of development. Most of these flies were collected with a mechanical trap in irrigated pastures, although some were examined from other situations which seemed probable places for oviposition. Of a total of 641 flies collected in 30 days, only 10 contained eggs, which were elongated and appeared to be mature. From 2 to 400 eggs were found per fly, with most of them containing fewer than 100.

SUMMARY—Studies at Summer Lake, Oregon, showed *Chrysops discalis*, *C. bishoppi*, *Tabanus sonomensis*, *T. productus*, and *T. punctifer* to be serious pests of livestock. Their habits of attacking and biting the animals vary according to species. The incidence on cattle is difficult to determine exactly, because the animals fight the flies. Counting flies on one side of cattle showed from 2 to 13 deer flies and 4 to 40 horse flies during 2 minutes. Other counts of 10 seconds showed up to 40 *C. discalis* and 50 *T. sonomensis*. An average of approximately 14 deer flies was observed landing on an animal to each 1 biting.

A calf penned inside a screen-wire trap attracted a total of 400 *C. discalis* and 27 *Tabanus* spp. in 1 hour. Rabbits proved poor hosts in attracting tabanids.

A rotating aerial trap consistently caught more males of *Chrysops discalis* during the morning than during the afternoon. The number of females caught did not show a consistent relationship with temperature or time of day. Other studies with the trap showed *C. discalis* to be the dominant species on alkali flats near the lake, while *Tabanus sonomensis* was the most numerous in irrigated pastures. The greatest number of *C. discalis* caught per hour was 333, while the record catch for *T. sonomensis* was 124.

Of the *Chrysops discalis* caught on adhesive-treated stakes 98 per cent contained mature eggs, as compared with 1 per cent of those capture over alkali flats. Eggs of *Tabanus sonomensis* had not been found in nature, and of 641 flies collected in 30 days only 10 contained mature eggs.

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ACRIDOLOGICAL ABSTRACTS, by Anti-Locust Research Centre. British Museum (Natural History), Cromwell Road, London, S.W. 7. 1950 to date.

Entomologists will be interested to know that a new abstract journal has been founded for review of papers dealing with locusts and grasshoppers. It is published by the Anti-Locust Research Centre whose director is the distinguished scientist, Dr. B. P. Uvarov. The Journal is mimeographed and is issued at irregular intervals to cover all publications on acridology from 1949 onward except the purely taxonomic papers. In 1950 four issues, which included abstracts of 142 articles, were published and in 1951 three issues, which included abstracts of 161 articles, have been published to date.

The value of these abstracts for entomologists conducting research on the physiology, ecology, and control of locusts and grasshoppers is considerable. First of all the abstracts are well written, in good style, and are informative. But aside from comparing favorably with abstracts of the older and established journals, they have these additional advantages: (1) Promptness, (2) Emphasis on grasshoppers and locusts, (3) Collection in one place, and (4) Completeness; *i.e.*, no paper is disregarded which is within the scope of coverage.

Dr. Uvarov has written to me that the Abstracts would be willingly supplied *gratis* to all earnest students of the problem, particularly those who are ready to help in making them complete. Authors can give this aid by sending bulletins or reprints of their papers (preferably in duplicate) to the Anti-Locust Research Centre. This refers both to currently published papers, and also to all earlier publications. In this writer's opinion it seems that sending one's papers to the Centre for abstracting not only helps the advancement of acridology but also gives the work of the author much more publicity than it would otherwise receive.

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Biosynthesis of Radioactive Pyrethrins Using $C^{14}O_2$

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In 1950 the biosynthesis of radioactive pyrethrins was undertaken in order to facilitate a fundamental study of the mode of action of pyrethrum insecticides by the Gulf Fellowship at the University of Illinois. Preliminary work by this Fellowship was hampered by the lack of an accurate microchemical method for the determination of pyrethrins. It was felt that the studies would progress more rapidly if tracers could be used to follow the metabolic path of the pyrethrins.

Various chemical syntheses were considered and rejected. Not only would it be extremely difficult and time consuming to synthesize Pyrethrin I or II or Cinerin I or II labeled in both acid and alcohol portions of the molecule, but unless all four compounds were synthesized and mixed, a product approximating the composition of a natural complex would not be obtained. For these reasons, a biosynthetic method of preparation involving (1) culture of intact pyrethrum plants for a prolonged period in an atmosphere containing $C^{14}O_2$, (2) isolation of the pyrethrins from the C^{14}-labeled flowers, and (3) purification of the pyrethrins was considered the most practical way of obtaining a randomly-labeled product entirely comparable to commercial pyrethrins (consisting of PI, PII, CI, and CII in a naturally occurring ratio).

In June, 1950, a preliminary study was made in which one pyrethrum crown was treated for 18 hours with $C^{14}O_2$ generated from one millicurie of $BaC^{14}O_3$. The flowers were harvested at maturity 4 to 10 days following treatment. The plant material became radioactive, but the purified pyrethrins showed negligible labeling. The low level of radioactivity was felt to be caused by the short treatment period and the possibility that a predominant portion of the pyrethrins precursors had been formed prior to the radiocarbon treatment.

Large-scale culture of a number of higher plant species from seedling to mature plant stages in a $C^{14}O_2$ atmosphere has been accomplished for some time at the Argonne National Laboratory, Chicago, Illinois, in hermetically sealed nutriculture chambers designed by Dr. N. J. Scully (Beal, 1949; Beal and Scully, 1950; Geiling *et al.*, 1948; Anonymous, 1952). Dr. Scully took an active interest in our work and provided invaluable information for a more extensive project.

Studies on the formation of pyrethrins in field grown plants show that the per cent of these substances in the flowers increases as the flowers develop and reaches a maximum in the mature flowers (Gnadinger, 1936). For this reason, and on the basis of the preliminary biosynthesis experiment, a six or seven-week treatment period prior to harvest was considered adequate to insure labeling of pyrethrins precursors and to obtain a randomly-labeled final product of specific radioactivity sufficiently high for tracer studies. The term, "treatment period," referred to in the text is defined as the 46-day period from the start of $C^{14}O_2$ treatment to the first harvest, at which time about 90 per cent of the plant material was removed.

In March, 1951, ten field-grown pyrethrum crowns, *Chrysanthemum cinerariaefolium* (Trev.) Bocc. = (*Pyrethrum*), in an early stage of development (no stem growth) were transplanted into a 5 by 5 foot field plot. The area was thoroughly weeded, and white painted boards were laid on the soil surface between the plants to discourage subsequent weed growth. A small metal-frame greenhouse (5 by 5 by 2.5 ft.) with glass sides and roof was placed over the plant plot. (Fig. 1). The greenhouse was hermetically sealed to an airtight wooden base which extended vertically 6 to 8 inches into tightly packed soil to minimize losses of gas by diffusion. The glass panes were bolted to the metal frame and were imbedded in a nonhardening, low carbonate mastic. One side of the roof was hinged to provide easy access to the plants. This "door" was bolted against a gasket of tubing[1] to form an airtight seal. It has been demonstrated that this material is impermeable to CO_2 while other similar materials and rubber permit rapid diffusion of this gas. To one end of the greenhouse was attached a collapsible

[1] *Tygon.*

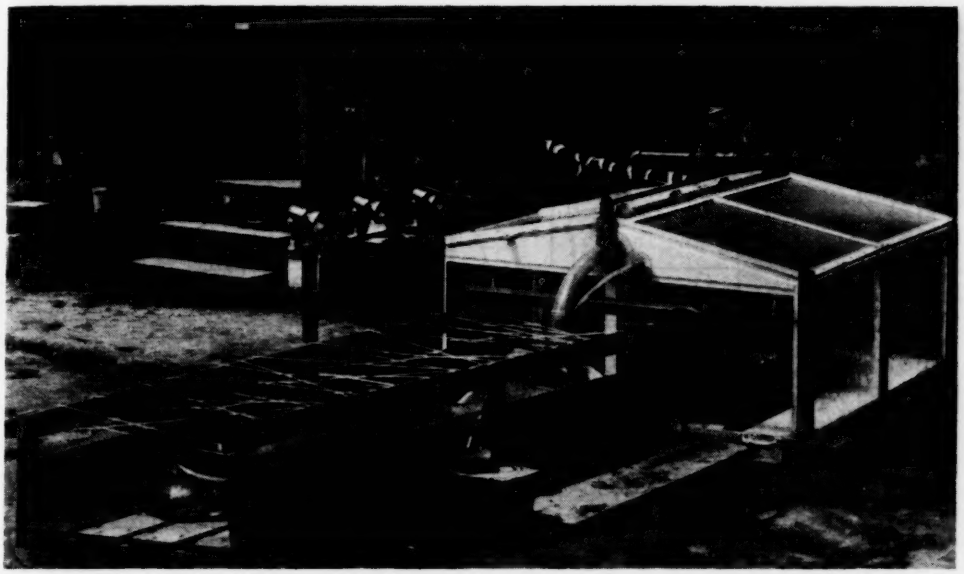

FIG. 1.

breather-bag of approximately 12-cubic foot capacity to insure a constant pressure of about one atmosphere within the sealed system. The other end of the greenhouse was fitted with gas inlet and outlet lines, wiring for temperature and humidity controls, an induction motor-driven fan, and tubing for a Freon refrigeration system. Three 150-watt spot lamps were placed externally along each of the other two sides of the greenhouse at a distance of about 3 feet. These lamps were used in cloudy weather in an effort to maintain utilization of CO_2.

The external system consisted of a gas generator, a Geiger counter with counting rate meter and continuous recorder, a Baird infrared gas analyzer and recorder, and a gas pump. Upon generation, the mixture of $C^{14}O_2$ and $C^{12}O_2$ was pumped into the greenhouse, the gas stream terminating back of the fan which continually circulated the air in the greenhouse. The gas flowed out of the greenhouse through a water-cooled spiral condenser, over a thin mica-window Geiger-Muller counter tube (window thickness, 1.4 mg./cm^2; Amperex 200 CB) into the infrared CO_2 analyzer, through a gas pump which was in continuous operation, and back into the generator. Condensed water was returned periodically to the greenhouse. By-pass valves permitted daily calibration of the CO_2 analyzer and changing of generators. All lines were constructed of tubing,[1] and all joints were sealed with a cement consisting of the tubing dissolved in cyclohexanone.

The temperature was controlled by flooding the roof and two sides of the greenhouse with cold water. The water supply was actuated by a solenoid valve and maintained the daylight temperature between 70 to 90° F. No attempt was made to control temperatures at night. At times the entire greenhouse was shaded with a layer of cheesecloth to prevent excessive temperatures. The average daily temperature for the treatment period was 75° F.; average maximum, 81° F.; average minimum, 63° F.

The relative humidity ranged from 50 to 70 per cent. At still higher humidities, it was felt that molding of plants might occur. While a small refrigeration unit was located inside the greenhouse for humidity control, this unit was not used because excessive humidities did not develop. The average daily relative humidity within the greenhouse during the treatment period was 64 per cent; average maximum, 72 per cent; average minimum, 56 per cent.

On advice from the Argonne group, an attempt was made to control the concentration of CO_2 in the greenhouse between 0.04–0.10 per cent during the daylight hours (8:00 a.m. to 8:00 p.m.). During the treatment period, the average day-

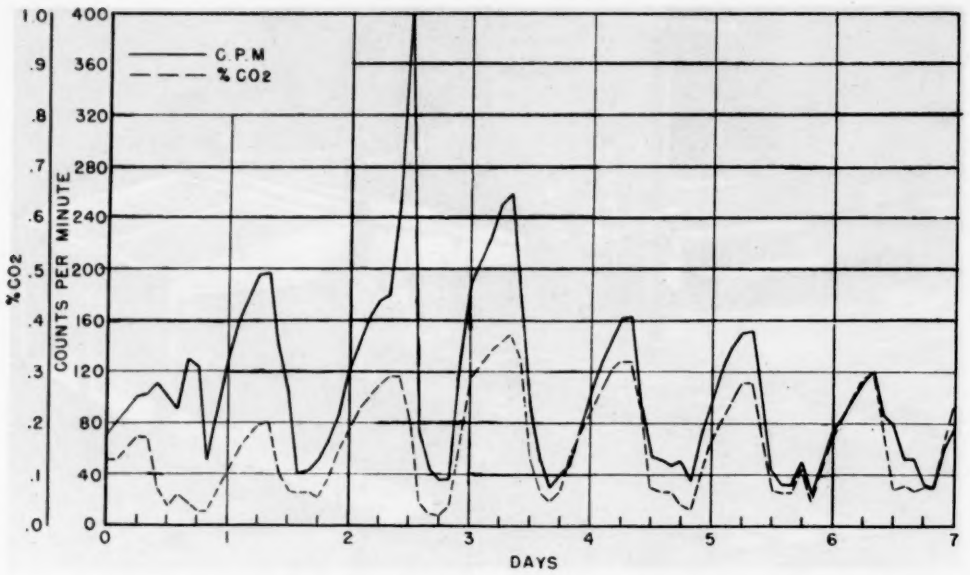

FIG. 2.—Daily record of CO_2 concentration and radioactivity levels during the third week.

time concentration of CO_2 was 0.11 per cent. No attempt was made to control the concentration of CO_2 at night (8:00 p.m. to 8:00 a.m.). This concentration sometimes ran as high as 0.5 per cent, mainly because of the small volume of the greenhouse (approximately 60 cu. ft.) in relation to the respiration capacity of the amount of plant material under cultivation. No evidence of injury to the plants was observed.

To prepare a generator, a calculated amount of $BaC^{12}O_3$ was placed in the generating flask. An aliquot of $BaC^{14}O_3$ concentrate (averaging 11.5 per cent C^{14}) was weighed into a porcelain boat supported on a strip of aluminum foil. The foil, boat, and $BaC^{14}O_3$ concentrate were then placed in the generating flask which was rotated gently to mix the contents. The average ratio of $BaC^{12}O_3$ to $BaC^{14}O_3$ concentrate was 1660; this ratio was chosen to provide adequate radioactivity of the pyrethrins. The acid reservoir was fitted to the generating flask, and the entire assembly was sealed into the system. The reservoir was filled with 1.5 times the required amount of 40 per cent lactic acid. The acid was added slowly in an effort to keep the CO_2 concentration in the greenhouse below 0.1 per cent. Attempts to eliminate foaming of the reaction mixture by slow addition of acid, stirring of the generator's contents, and addition of small amounts of D. C. Fluid 200 were all partially successful. Before a spent generator was removed, the contents were heated to 60–70° C. for 15 to 20 minutes to insure complete reaction and to minimize solubility losses of $C^{14}O_2$.

The system and all equipment were tested for several days with $C^{12}O_2$ under the proposed operating conditions and were found to be gastight and to function satisfactorily. On April 30, 1951, the first charge of $C^{14}O_2$ was admitted. During the first 10 days a low order of radioactivity was observed due to dilution of the $C^{14}O_2$ by air in the system and release of CO_2 from the plants, particularly at night. After this initial period, build-up of activity, as shown by the night counts, was rapid. The plants developed normally although faster than plants in the field because of higher temperatures in the greenhouse. By the forty-sixth day, over 90 per cent of the flowers had reached the harvest stage. The CO_2 concentration was allowed to approach zero, and the radioactivity level was allowed to approach background (20 cpm.). The door was opened, and the mature flowerheads and extraneous plant material were harvested. The soil was treated with sodium dihydrogen phosphate solution to release combined CO_2 from the soil, and the door was resealed. The remaining plants were treated for 10 days and then harvested.

Figure 2 is a record of CO_2 concentra-

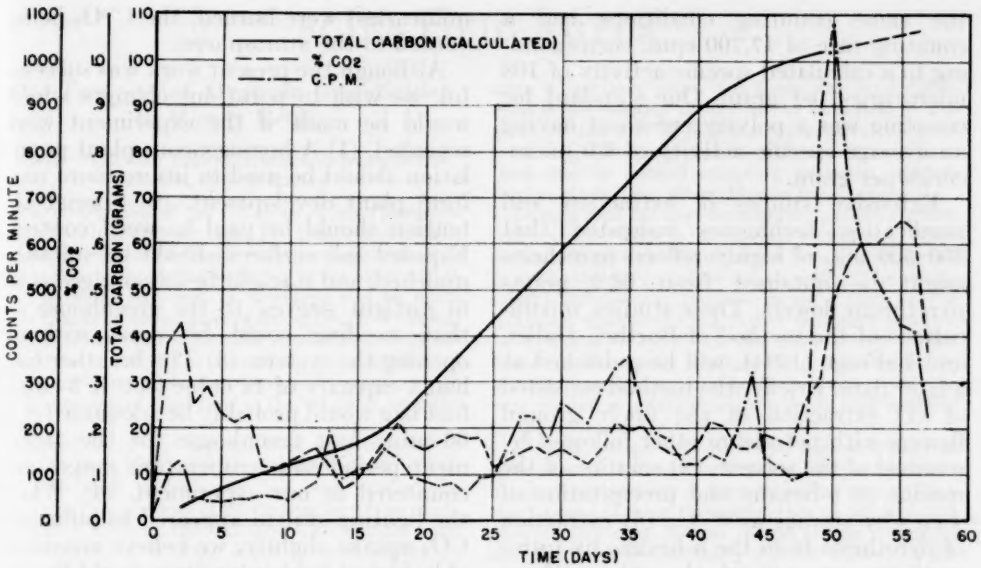

FIG. 3.—Average daily variation in total carbon content, CO_2 concentration and radioactivity level.

tion and radioactivity level taken during the third week of the treatment period. It illustrates the rapid utilization of CO_2 during the hours of high light intensity and the reasonable correlation between CO_2 concentration and the level of radioactivity in the gas phase. As the light intensity decreased (6:00 p.m. to 7:00 p.m.), the plants began to lose CO_2; this night loss continued until about 8:00 a.m. On the basis of the over-all experimental data collected, it is estimated that as much as 15 per cent of the daily uptake of CO_2 may be released at night.

Figure 3 shows the day to day variations of CO_2 concentration, radioactivity level, and the calculated total carbon content of the plants (pyrethrum and weeds). A high per cent CO_2 and low radioactivity level prevailed during the first 12 days. During the next 34 days, a high CO_2 concentration was attended by a relatively high radioactivity level. The carbon content is a measure of the amount of total plant growth. The total carbon content was based solely on that derived from $BaCO_3$ and does not consider a possible soil source of carbon. It may be seen in figure 3 that the period from the seventeenth to the fortieth day is the period of most rapid growth. After the fortieth day the carbon content curve levels off indicating that maximum growth has occurred.

A total of 45 millicuries of $BaC^{14}O_3$ (1.1 grams) purchased from the Atomic Energy Commission was used. About 41 millicuries were used during the treatment period, and the remainder during the next 10 days. The harvested material was oven-dried at 125° F. for 8 hours and then air-dried at room temperature for 72 hours. The total dry plant material weighed 522.2 grams and consisted of 62.2 grams pyrethrum flowers, 154.4 grams pyrethrum stems, 95.4 grams leaves, 96.3 grams pyrethrum roots, and 113.9 grams weeds (broad leaves, grasses, etc.)[1] Based on analyses of the pyrethrum flowers in previous years, a maximum yield of 740 mg. pyrethrins was expected.

Determination of radioactivity of the product at various stages of processing gave the following results: fresh pyrethrum flowers, 5720 cpm; dry pyrethrum flowers, 9000 cpm. These measurements were taken at 2.1 cm. from the mica window of an Amperex-type 200 CB Geiger-Muller counter tube using a baffle with a $\frac{5}{8}$-inch hole directly over the sample. The counting rate of the ground flowers (20 mesh) at a distance of 3.0 cm. from an Amperex 200 CB type tube using a baffle with a $\frac{3}{4}$-inch hole was 34,100 cpm. Resinous and waxy material associated with the pyrethrins, in a thickness which exceeds the range of beta rays (that is, effectively, of infinite thickness), under

[1] About half of the pyrethrum stems and leaves and some of the weeds were given to Dr. Ralph Buchsbaum, University of Pittsburgh, for preparation of invertebrate culture media for tracer studies.

the same counting conditions had a counting rate of 47,700 cpm. corresponding to a calculated specific activity of 108 microcuries per gram. Our standard for counting was a polystyrene sheet having an average specific activity of 2.0 microcuries per gram.

Extensive studies of extraction and purification techniques indicated that 300–500 mg. of highly refined pyrethrins might be obtained from 62.2 grams pyrethrum flowers. These studies, modifications of the method of Barthel, Haller, and LaForge (1944), will be published at a later date. Briefly, the method consisted of (1) extraction of the finely ground flowers with petroleum ether followed by removal of the solvent, (2) solution of the residue in n-hexane and precipitation of waxes by storage at 0° C., (3) extraction of pyrethrins from the n-hexane by nitromethane, passage of the nitromethane solution through activated carbon and removal of the nitromethane. All solvents were removed *in vacuo* at or below room temperature. The yield of pure pyrethrins was about 400 mg. which was immediately dissolved in n-hexane and stored in the dark at 0° C. A portion of the purified pyrethrins solution was given to the Gulf Fellowship at the University of Illinois. Mr. Norman Earle of this Fellowship, under the direction of Prof. C. W. Kearns, has completed studies on house flies and roaches which indicate that the pyrethrins have the expected insecticidal activity. He has also shown that the pyrethrins are labeled with C^{14} in both alcohol and acid portions of the molecules at level high enough for qualitative and quantitative determinations.

Extreme care was taken in handling the $BaC^{14}O_3$ powder and in grinding the dried flowers to prevent inhalation of solid radioactive particles. All radioactive wastes which could not be stored (1 to 2 millicuries) were burned, the $C^{14}O_2$ being vented to the atmosphere.

Although the present work was successful, we wish to point out changes which would be made if the experiment were repeated. (1) A homogeneous plant population should be used to insure more uniform plant development. (2) Special attention should be paid to weed control. Exposed soil surfaces should be suitably mulched, and it might be advantageous to fit airtight sleeves[1] to the greenhouse so that weeding could be done without opening the system. (3) The breather bag had a capacity of 12 cubic feet. A 3-cubic foot bag would probably be adequate for a 60-cubic foot greenhouse for the treatment period and temperature ranges encountered in our experiment. (4) While the lighting system appeared to influence CO_2 uptake slightly, we believe considerably higher light intensities would be desirable. (5) One of the two lots of $BaC^{14}O_3$ used was extremely concentrated. Less concentrated $Bac^{14}O_3$ would facilitate weighing and dilution with $BaC^{12}O_3$. (6) The infrared CO_2 analyzer employed sodium chloride cell windows. The instrument's tendency to drift was presumably caused by differential clouding of the sample cell windows by moisture in the gas stream. It is believed that calcium fluoride cell windows would function more satisfactorily. (7) Prior to sealing the system, about twice the estimated water requirement of the plants was added. In the case of longer treatments, provision should be made to add water as it is required.

The authors wish to thank their associates, W. J. Happel, R. G. Russell, and C. W. Tittle of the Physics Division, and the personnel of other Divisions for their co-operation in helping to bring this project to a successful conclusion.

[1] Made of *Tygon*.

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SCIENTIFIC NOTES

The Toxicity of Organic Insecticides to Honey Bees[1]

NEVIN WEAVER, *Texas Agricultural Experiment Station, College Station*

The evaluation of the toxicities of insecticides to honeybees is a difficult task. The number of bees in a field is influenced by so many ecological factors and instincts connected with the social mode of life that no valid estimates of mortality can be made from counts of the number of living bees in a treated field. Estimates of the mortality due to an insecticide should be based on the reduction of the number of bees in colonies visiting treated fields, or on counts of the number of dead bees in the field and near the hive.

Regardless of the method used it is imperative that the bees visit no fields except those to which the insecticide under study has been applied. In this area, the only way of preventing bees from visiting cotton fields to which different insecticides have been applied is to allow them to work cotton in cages. This method has been employed for the past 3 years, and although the bees appear to work quite normally in the cages there is no certainty that their behavior is not considerably modified by confinement. Also, bees will not behave as a colony unless there are fairly large numbers of them in the hive, and it is not feasible to build cages large enough for the field force to have a normal area in which to work. The resulting over-crowding makes it impossible to estimate the absolute toxicity of an insecticide by this method, but it is believed that a fairly good estimate of the relative toxicities of the insecticides can be obtained. Since the sampling error in any given observation may be large and since many ecological and physiological factors may affect the toxicity of an insecticide, repeated observations are necessary for a good estimate of toxicity.

The method of keeping bees in cages 36 feet long set up over two rows of cotton has been described (Weaver 1950, 1951). Studies using this technique were continued in the summer of 1951 in the Brazos River Valley near College Station. As in previous tests, a cage in which no insecticide was used served as a check and only one insecticide was applied in any other cage. A severe drou.h during the summer virtually stopped nectar secretion for several weeks, but six tests were conducted when there was a normal amount of nectar. The following dusts were applied in dosages ranging from 5 to 20 pounds per acre: (1) 3 per cent gamma benzene hexachloride–5 per cent DDT–40 per cent sulfur (3-5-40), (2) 10 per cent DDT–40 per cent sulfur, (3) 10 per cent chlordane–40 per cent sulfur, (4) 20 per cent toxaphene–40 per cent sulfur, and (5) 2.5 per cent dieldrin. The average percentages mortality for the first 3 days following application of an average of 13 pounds of dusts per acre are shown in figure 1.

All of the materials except chlordane were more toxic in 1951 than in 1949 and 1950. The reason for this increased toxicity is not known. Some of the tests were conducted late in the fall when the average temperature was much lower than during the tests in previous years, but there was little difference in the toxicity of any of the materials at low temperatures and at higher temperatures the same year. Any differences that were observed could have been due to normal sampling variation, though further study may show them to have been real.

During 1951 the bees consistently gathered pollen from cotton. This is in marked contrast to their action in 1949 and 1950 when few bees were observed to even attempt to gather cotton pollen. The reason for this difference in behavior is not known, nor is it known whether or not higher mortality resulted from this activity. Since the flowers were closed when the dusts were applied, the pollen could have become contaminated only from dusts from the surrounding vegetation or from dusts that adhered to the bodies of the bees.

Dieldrin consistently produced high mortality in spite of a marked repellent effect. There was always a fair concentration of bees gathering nectar for a short time following the application of dieldrin, but soon the number of bees in the cotton decreased sharply. Since the mortality was the highest on the second day, and since on that day bees which ap-

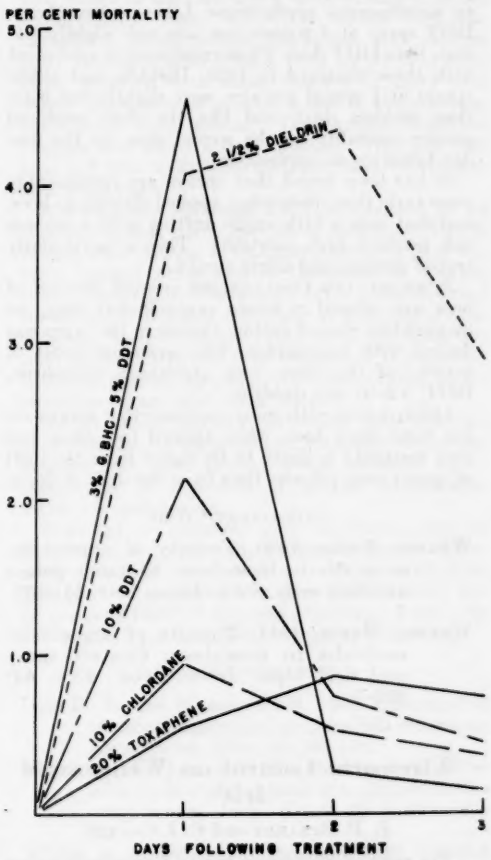

FIG. 1—Average percentages mortality of honeybees for the first three days following applications to cotton of insecticides as indicated.

[1] Technical Contribution No. 1567. Texas Agricultural Experiment Station.

peared to be young were found dead immediately in front of the entrance of the nucleus, it is probable that some of the mortality resulted from contaminated nectar which was carried into the hive. The total mortality due to six applications of this material was 54.6 per cent of the bees in the nucleus.

The mortality due to 3-5-40 was, as in the past, high on the first day following the application of the insecticide and low on subsequent days. This material was markedly less repellent during the tests in 1951 than in 1950 and produced considerably higher mortality, but chlordane which was also less repellent in 1951 produced lower mortality than in 1950. Chlordane produced only 6.6 per cent, 3-5-40, 19.2 per cent mortality during the season.

DDT and toxaphene again exhibited little repellency to the bees and neither was highly toxic. As in previous years, the mortality due to DDT was much higher on the first than on subsequent days following application of the dust, and toxaphene produced a higher mortality on the second than on any other day. The mortality due to DDT was 13.6 per cent, due to toxaphene 11.6 per cent, during the season.

Limited tests were conducted with dieldrin, aldrin, toxaphene, and toxaphene-DDT (2-1) sprays. Toxaphene spray at 2 pounds of active ingredient per acre was slightly less toxic than toxaphene dust on simultaneous applications. Likewise toxaphene-DDT spray at 2 pounds per acre was slightly less toxic than DDT dust. These results are in agreement with those obtained in 1950. Dieldrin and aldrin sprays at ¼ pound per acre were slightly less toxic than dieldrin dust, and like the dust produced greater mortality on the second than on the first day following an application.

It has been found that sprays are considerably more toxic than dusts when applied directly to bees, and that only a little spray drifting in to a nucleus will produce high mortality. This is particularly true of dieldrin and aldrin sprays.

SUMMARY AND CONCLUSIONS.—Small colonies of bees were placed in screen cages 36 feet long, set up over two rows of cotton. Cotton in the cages was dusted with insecticides. The ascending order of toxicity of the dusts was: chlordane, toxaphene, DDT, 3-5-40, and dieldrin.

Limited tests with sprays indicate that sprays are less toxic than dusts when applied to cotton, but that mortality is likely to be higher from the drift of sprays onto colonies than from the drift of dusts.

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Wireworm Control on Wedgewood Iris[1]

E. P. BREAKEY and C. J. GOULD[2]

The purpose of this test was to determine whether or not iris bulbs could be protected against wireworm injury by treating the bulbs with an insecticide before they were planted. Since the bulbs are usually given a fungicidal pre-planting dip[3] with thiram, the test was also designed to learn whether or not the presence of the dip[3] would have any effect on wireworm injury or would affect the insecticidal activity of the insecticides used.

Table 1.—Wireworm Control. Wedgewood Iris—1951.

TREATMENT	CONCENTRATION PARTS BY WEIGHT IN WATER	TOTAL BULBS	INJURED BULBS	MEAN NUMBER INJURED PER TREATMENT
Untreated	—	517	292	48.67
Thiram	1:75	511	241	40.17
Thiram plus BHC (100%)	1:200	540	71	11.83
Thiram plus DDT (100%)	1:80	511	184	30.67
Thiram plus Dieldrin (100%)	1:200	537	99	16.50
BHC (100%)	1:200	511	86	14.33
Difference required for significance at 5% level				10.24
Difference required for significance at 1% level				13.85

MATERIALS AND METHODS.—Wedgewood iris bulbs of assorted sizes were available from fertilizer trials of the preceding year. These ranged in size from 10 to 11 cm. to below 5 cm. They were graded into sizes and each size distributed equally throughout the test. Six replicates of 100 bulbs each were used.

The following materials were employed in this test:

Thiram, Tetramethyl thiuram disulfide, 50% (duPont)

Benzene hexachloride, 25 per cent wettable

DDT, 50 per cent wettable

Dieldrin, 25 per cent wettable

With the exception of thiram, the strength of each dip was computed on the basis of 100 per cent of the active ingredient. The bulbs were dipped for 10 minutes and planted in soil infested with wireworms[4] on a farm near McMillan. All dipping and planting were done on October 16, 1950.

EXPERIMENTAL RESULTS.—The bulbs were taken from the soil as soon as mature, allowed to cure according to accepted procedure, then cleaned for examination and scoring. All data are based on round bulbs, since it was nearly impossible to keep the slabs from becoming detached from the larger bulbs, and their identity would thus be lost.

The data are summarized in table 1. It will be noted that the thiram dip alone appears to have had some effect in preventing wireworm damage, though not significantly. According to the means, however, there is no significant difference between the treatments of thiram plus BHC, thiram plus dieldrin, and BHC alone. Both BHC and dieldrin were highly significantly superior in control when compared with the check. The difference between the thiram and the thiram plus DDT treatments is not significant but approaches significance. The thiram plus DDT treatment gave significant control of wireworms when compared with the check, though this treatment falls considerably short of the others in effectiveness.

[1] Scientific Paper No. 1102, Washington Agricultural Experiment Stations, Pullman.

[2] Associate Entomologist and Associate Plant Pathologist, respectively, Washington Agricultural Experiment Stations, Western Washington Experiment Station, Puyallup.

[3] With "*Tersan*" (duPont).

[4] Probably *Limonius canis* Lec. since this species is known to be a pest in this locality.

Control of Red-Backed Cutworm with Toxaphane and Methoxychlor Dusts[1]

E. C. KLOSTERMEYER, *Irrigation Experiment Station, Prosser, Washington*

Cutworms, particularly the red-backed cutworm, cause damage to corn, sugar beets, hops, and other crops nearly every spring in irrigated central Washington. Usually infestations are not reported early enough or are not sufficiently uniform to permit replicated experimental control investigations.

On May 1, 1951, a heavy infestation of the red-backed cutworm, *Euxoa ochragaster* (Guenee), was reported damaging Ranger alfalfa near Grandview, Washington. Alfalfa seed which was not harvested because of rain had been produced in this field the previous year. As a result, much plant residue remained in the field and provided excellent overwintering conditions for the worms.

The cutworms were about half grown when discovered. Preliminary counts indicated an infestation averaging about 50 worms per square foot, uniformly distributed through the field. In spite of the heavy infestation, little damage had resulted except where the alfalfa stand was thin. Much of the feeding was confined to seedlings which were sprouting from shattered seed of the previous year. However, by May 21, plants in parts of the field were almost completely stripped of leaves. Considerable damage resulted when the cutworms cut through the tender stems below the tips.

MATERIALS AND METHODS.—On May 7, six insecticide treatments were applied to 6 by 6 foot square plots arranged in three randomized blocks in the field. Untreated plots served as controls. Each block contained seven plots arranged in a line down the irrigation rills. Treatments were separated by untreated 6-foot borders. All insecticides were applied as dusts with a knapsack bellows duster at about 30 pounds per acre.

The following materials were used: 10-per cent toxaphene, 10-per cent methoxychlor, 5-per cent chlordane, 1-per cent dieldrin, 10-per cent DDT, and 1-per cent aldrin. The aldrin and dieldrin were prepared by diluting wettable powder concentrates with talc. The other dusts were commercial preparations.

Counts of the dead and dying cutworms on the surface of the soil in each plot were made at intervals after treatment. The first count was made after 36 hours, and the final count was made 2 weeks after treatment. In addition, 1 week after the dust treatments, four 0.25 square foot soil samples were removed to a depth of 2 inches and examined for living cutworms.

RESULTS.—Since the variances of the individual treatments were proportional to the means, the data were converted to $\sqrt{n+0.5}$ and the analysis of variance computed on the transformed values. The mean values for the transformed data, and the worm counts computed by squaring these means, are given in table 1. Differences among the treatments were highly significant. Toxaphene acted rapidly and affected more worms than any other material tested. Methoxychlor had a rapid initial effect but killed fewer worms during the period of observation. Chlordane and DDT had little effect either immediately or over a period of time. Dieldrin and aldrin killed few worms initially, but became slightly more effective later.

Table 1.—The effects of insecticidal dusts on red-backed cutworm populations in alfalfa.

Insecticide Used	Moribund Worms per Plot Following Treatment			
	36 Hours		Total During 2 Weeks	
	$\sqrt{n+0.5}$	No. of Worms[1]	$\sqrt{n+0.5}$	No. of Worms[1]
10% Toxaphene	19.1	366	35.7	1271
10% Methoxychlor	15.8	249	21.3	452
5% Chlordane	4.6	21	12.3	152
1% Dieldrin	2.5	6	10.0	101
10% DDT	5.6	31	7.8	61
1% Aldrin	2.1	4	6.5	43
Check	0.8	1	3.0	9
Standard error of differences	0.8	—	2.8	—

[1] Computed by squaring $\sqrt{n+0.5}$.

Differences among the mean numbers of worms per square foot of soil samples 1 week after treatment were not significant. The toxaphene and methoxychlor treatments had the fewest worms remaining in the soil.

Samples of affected larvae from each treatment were caged in the laboratory to determine if death would finally result. All of the worms from the toxaphene, methoxychlor, chlordane, and dieldrin plots were dead after 5 days. Only 50 per cent mortality occurred with those exposed to DDT and aldrin. Symptoms of poisoning due to the different insecticides were similar. The worms exhibited tremors and rolled about violently. They did not feed and eventually shriveled and died. Death was slow in all cases.

DISCUSSION.—Although DDT is reported to be effective against many species of cutworms (Hill & Muma 1951; Whipp & Chapman 1951), it is of less value against other species (Weinman & Decker 1951). Farmers in Washington often have reported the failure of DDT or chlordane to give appreciable cutworm control. On the other hand, favorable results had been reported from toxaphene. It is evident that considerable specificity in susceptibility to insecticides occurs with these insects.

Methoxychlor has not previously been reported as of value for cutworm control. Results of this study indicate that methoxychlor would be useful where application of materials of greater mammalian toxicity is undesirable.

SUMMARY.—Toxaphene gave excellent control of the red-backed cutworm, *Euxoa ochragaster* (Guenee), on alfalfa when used as a 10 per cent dust. Ten per cent methoxychlor gave good control, but 10 per cent DDT, 5 per cent chlordane, 1 per cent aldrin, and 1 per cent dieldrin were of little value.

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[1] Scientific Paper No. 1091, Washington Agricultural Experiment Stations, Pullman. Project No. 1062.

Relative Efficiency of Methods of Applying Lindane in Enclosed Spaces[1]

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In 1950 Fulton *et al.* (1950) carried out tests in which they treated enclosed spaces with lindane by spraying the walls with a suspension of a water-dispersible powder or by applying a liquefied-gas aerosol. The spray was applied at the rate of 25 mg. of lindane per square foot and the aerosol at 100 mg. of lindane per 1000 cubic feet. The air was analyzed for the presence of chlorine. The vapors from the lindane when applied by either method showed a definite fumigating action. The house fly, *Musca domestica* L., and the banded greenhouse thrips, *Hercinothrips femoralis* (Reut.), were found to be susceptible to traces of lindane (1.7 mg. per 1000 cu. ft.). The melon aphid, *Aphis gossypii* Glov., was susceptible to concentrations above 28 mg. per 1000 cu. ft.

Further studies were made during the 1951 season to determine the amount of lindane vapor that might be found in enclosed spaces where no ventilation was provided. For these tests four airtight chambers of 3000 cubic feet each were used in which to compare four methods of applying lindane. As the units had no windows, illumination was provided with two 40-watt fluorescent light bulbs. The walls and ceiling had been painted with aluminum paint. The floors of all the units were covered with straw which was changed frequently.

PROCEDURE.—The walls and ceiling of one unit were sprayed at the beginning of the test with a suspension made from a 25-per cent lindane water-dispersible powder at the rate of 25 mg. of lindane per square foot. The second unit was provided with an air-circulating device (Sullivan 1951) by means of which the air was blown continuously through a fiber-glass filter which had been sprayed with an acetone solution of lindane. The third unit was treated with an electrically heated vaporizer that was set to operate continuously and maintain the temperature of the lindane at 113–116° C. The fourth unit was treated weekly with a carbon dioxide-propelled solution of lindane at the rate of 300 mg. of lindane per 1000 cu. ft. The composition of this solution (G-939) was as follows: Lindane 1 per cent, cyclohexanone 50 per cent, acetone 45 per cent, and carbon dioxide 4 per cent. The carbon dioxide was added to bring the pressure to 150 pounds per square inch.

At weekly intervals throughout the experimental period air analyses and house fly mortality tests were made by the procedure followed in the initial work. These tests were made after the doors of the units had been closed one hour.

RESULTS.—The results of the chemical analyses and the house fly mortality tests are shown in table 1. The results corroborated previous findings and showed that in enclosed spaces the lindane vapors were always present regardless of the method of application. The maximum amount of lindane found with any method was 21.8 mg. per 1000 cubic feet.

Where the walls had been treated with the suspension, the vapors from the residue remained effective for approximately 2 weeks. The deposit of the lindane powder had been visible, but at the end of this period it was covered with dust from the straw on the floor. After that, chemical analyses and cage tests showed a definite decline in vapor concentration.

The lindane in the vaporizer was weighed after the tests and it was found that approximately 750 mg. of lindane had been vaporized per day. Analyses of the air showed the presence of lindane, but after 15 days of operations the vapor was not effective even though a crystalline deposit of lindane approximately 5 feet in diameter was on the ceiling above the vaporizer.

The carbon dioxide-propelled solution appears to be an efficient method of applying lindane. Only 0.33 gram of lindane was used per 1000 cubic feet at weekly intervals, and the deposit on the walls and ceiling remained effective for 5 to 8 days.

The fan blowing over the lindane-coated air filter is also an efficient way of applying lindane within enclosed spaces when only low concentrations of vapor are necessary. However, the air was so dusty that after 2 weeks' use the screen became clogged and had to be cleaned to restore its effectiveness. Therefore, to obtain the maximum efficiency from this type of device where the air is dust-laden, a dust filter should be placed ahead of the lindane-treated screen.

CONCLUSIONS.—The four methods of applying lindane produce a satisfactory concentration for the control of insects that are susceptible to low concentrations of vapor. In air-tight units little difference was found in concentrations of lindane vapor irrespective of the method used. A suspension of the water-dispersible powder when applied to surfaces within enclosures loses its effectiveness when the deposit becomes covered with dust. To maintain an

Table 1.—Effectiveness of four methods of applying lindane in enclosed spaces as shown by chemical analysis of air and mortality of house flies.

TIME AFTER TREATMENT	TEMPERATURE, °F.	LINDANE, MG./1000 CU. FT.	MORTALITY AFTER 10 MINUTES	MORTALITY AFTER 60 MINUTES
		Suspension Spray		
1 hr.	70	4.8	48	99
1 day	71–72	21.8	35	97
6 days	76–77	7.4	99	99
15 days	73–74	2.4	13	27
21 days	77–78	0.96	7	28
		Lindane Screen with Fan		
1 hr.	74	4.8	77	100
1 day	71–72	11.9	35	100
6 days	77–79	17.0	97	100
15 days	72–73	Present[1]	45	99
21 days	77–78	11.9	21	76
		Vaporizer		
1 hr.	74–76	4.8	18	51
1 day	71–73	19.5	19	32
6 days	77–78	5.9	65	100
15 days	73–74	0.96	0	20
21 days	77–78	Present[1]	0	9
		Carbon dioxide-propelled solution		
1 hr.	77–78	11.9	100	100
5 days	72–71	11.9	11	31
6 days	75	Present[1]	1	64
8 days	77	1.4	0	42

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 10–13, 1951.

[1] No definite determination could be made because of interference from the sodium arsenite solution.

adequate concentration the walls and ceiling should be sprayed at 2 to 3-week intervals.

Screens treated with lindane should be protected with air filters; otherwise they will become useless when covered with dust. The location of vaporizers to obtain the maximum air transfer in the room should be selected by trial to obtain uniform concentrations. The vaporizer units should be checked regularly to determine the operating temperatures and to remove any accumulation of lindane.

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A Parasite of the Vegetable Weevil[1]

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A study of the biology and control of the vegetable weevil, *Listroderes costirostris obliquus* Klug, has been in progress during the past several years at Experiment, Georgia. In January 1951, while dissecting adult vegetable weevils for studies on internal morphology, a dipterous larva was found to be present as an endoparasite. Several specimens of the parasite were reared to adults and identified as *Hyalomyodes triangulifera* (Loew) (family Larvaevoridae).[3] This is the first record of rearing an insect parasite from the vegetable weevil in the United States.

To determine the extent of parasitism a series of dissections were made during January 1951, October 1951, and January-February 1952. All of the vegetable weevils were collected in the field and dissected in the laboratory on the same or the following day. Dissection of 107 adult vegetable weevils during January 1951 showed 19.62 per cent parasitism. The parasite larva was located in the abdomen, and only one was present in each adult. A few vegetable weevil larvae were dissected at the same time, but no parasites were found. On October 30, 1951, a total of 29 weevils were dissected, but no parasites were found. Subsequent dissections from January 9 to February 8, 1952, showed 12.55 per cent of 462 adult weevils parasitized. Two individuals had two parasites present.

Little is known of the life history and habits of this parasite. The only information obtained was on the length of the pupal stage. In laboratory rearings, several pupae were found to spend from 17 to 22 days in this stage, an average of about 19.5 days. The parasite larvae emerged from the host before entering the pupal stage.

Fattig (1949) has previously collected *Hyalomyodes triangulifera* from four locations in north Georgia: Cartersville, Neel Gap, Rome and Sarah. All of these collections were made during May or June. Apparently the specimens were collected by sweeping since no host records were given. According to Muesebeck (1951) this parasite apparently is widely distributed. It seems to occur as far south as Argentina since it may be the species referred to by Parker *et al.* (1950). Muesebeck further stated that, according to available records, this fly parasitizes the adults of a number of different kinds of beetles. However, no specific host was mentioned.

Previous workers have failed to find any insect parasites of the vegetable weevil in the United States. Blanchard (1943), Compere (1946), and Parker, *et al.* (1950) have reported investigations conducted in Argentina and Uruguay on parasites of vegetable weevils. A number of these parasites were sent to the United States and released in California, but none is known to have become established. In view of these reports the occurrence of this parasite of the vegetable weevil in Georgia is significant.

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Ethylene Dibromide Fumigation of Mangoes and Almendras Infested with *Anastrepha* Fruit Flies

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Ethylene dibromide fumigation has recently been found very effective against the Mediterranean and oriental fruit flies and the melon fly in Hawaii (Balock 1951), and it has been approved for the treatment of various Hawaiian fruits including papaya, guava, and avocado.[2] An investigation was therefore made to determine whether it could be used effectively against the West Indian fruit fly, *Anastrepha mombinpraeoptans* Sein, infesting mangoes and *A. suspensa* (Loew) infesting almendras in Puerto Rico.

Ethylene dibromide is a clear liquid (b.p. 131° C.) which has been widely used as a soil and grain fumigant. At present it is a rather critical war chemical being used in the manufacture of high-octane gasoline, but some amount is still being allocated for agricultural fumigation purposes. Its present cost is about 42 cents per pound in 5- to 10-gallon lots (90 to 180 pounds). The liquid is about twice as heavy as water and its gas is six times as heavy as air. The liquid solidifies at 10° C.

PROCEDURES.—A total of 127 groups of fruit were exposed in 20 fumigations involving approx-

[1] Paper No. 222, Journal Series, Georgia Experiment Station, Experiment, Georgia.

[2] Acknowledgment is made to Harold Colwell for assistance in collecting and dissecting vegetable weevils.

[3] Determined by S. W. Sabrosky, Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U.S.D.A.

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[2] U. S. Bur. Ent. & Plant Quar. SRA 592.

imately 12,000 fruit fly larvae, of which 3300 were examined individually. Approximately 6600 mangoes in trays, crates, and other containers were used. In addition 11 fumigations were made of almendra nuts. In most of the fumigations the load was small as compared with total space available, but in the last two approximately 45 and 55 per cent of the space was occupied.

All fumigations were made at the Insular Government fumigation plant near Pier 14, San Juan, Puerto Rico. In a 300-cubic foot steel fumigation chamber a hotplate with a vaporizing pan was installed near the top center, and an injection tube was fitted just above it so that the liquid would flow by gravity directly into the vaporizing pan. The hotplate was heated to sizzling, and the heat was shut off just before the start of each fumigation. Preliminary tests had shown that the residual heat was sufficient to vaporize a dosage of 24 cc. (equals 6 ounces by weight per 1000 cubic feet) in about 5 minutes. All fumigations were made at dosages of 6 ounces or less except in two mango-tolerance tests, when 8 and 12 ounces were used. Continuous air circulation was provided by an 18-inch fan set on the floor at one end of the chamber. In most of the tests air and fruit temperatures were 85–87° F. In some tests the fruit was precooled to near 50° F. before fumigation and then kept at this temperature for 5 days after fumigation to simulate cold storage conditions during an ocean voyage to New York.

It was necessary to bring infested mangoes from Mayaguez at weekly intervals, since those available locally in San Juan (Blanco and Cubano) were found to be only lightly infested with fruit flies. Few, if any, guavas were ripe at the time of the tests to provide infestations of *Anastrepha suspensa;* so infested almendra nuts were used. The mango varieties Haden, Martinique, D. B. Alphonse, Amini, Cambodiana, Bulbulchaam, Sandersha, Sufaida, and Totefari were brought from Mayaguez and varieties Salavari, Pahari, Hequero, Titenanan, Manzano, Belen, and Julie from the island of Viques for tolerance tests. In the last two tests 37 crates of the Mayaguezano variety were used.

Fumigated mangoes and almendras were kept for 2 to 3 weeks in screen-wire emergence cages. These cages were examined every day or two to record emergence of larvae, remove pupae, and replace blotting paper when necessary. In most of the tests fruits were also cut up and examined several days after fumigation to determine mortality of larvae; other fruits were examined at the end of the holding period for possible egg hatching and presence of viable larvae.

In addition to infested fruit, full-grown larvae and pupae were exposed directly to the fumigation. Eight untreated trays of mangoes and two of almendras were carried through to give data on the degree of infestation present. The identities of the two species of fruit flies were verified by Alan Stone, Division of Insect Identification.

RESULTS.—All larvae and pupae of both species of fruit flies in mangoes or almendras were killed in all the tests made at dosages of 2 to 6 ounces of ethylene dibromide per 1000 cubic feet. A 1-ounce dosage, tried only on *Anastrepha mombinpraeoptans* was believed to be near the lower effective limit, as some larvae were still alive though moribund 3 to 4 days after fumigation; all died by the fifth day, however. At dosages of 3 to 6 ounces in the small-load fumigations all larvae were dead within 2 to 3 days. Complete mortality was also obtained in the two larger load tests at 4- and 6-ounce dosages. The crates in these tests were stacked so that there was good air space between them. Out of the hundreds of larvae examined in the 4-ounce test, there were two active larvae inside two fruits after 3 days and one after 5 days but they died by the sixth day. Apparently this dosage is near the lower limit of complete efficiency under large-load conditions, and the 6-ounce dosage would allow a better margin of efficiency.

No pupae developed from any of the unexamined mangoes or almendras exposed in any of the fumigations. Unfumigated mangoes of the same varieties as those used in the gas-efficiency tests averaged four to five pupae per fruit. Almendra nuts averaged near three per nut.

Until more information is obtained, it is advisable to pack the crates very loosely in the fumigation chamber so that space is left around each box, and to restrict the load to not over 50 per cent of the available space.

No exact observations were made on the eggs, but it seems safe to assume that some eggs were present on the fumigated fruit, especially on the heavily infested mangoes brought directly from the field at Mayaguez, and that these eggs would hatch and develop if not killed by the fumigation.

Penetration of the fumigant into commercially packed crates containing over 100 mangoes was indicated to be satisfactory, as all larvae in the crates were killed. These crates contained three layers of closely packed fruit with clipped newspaper packing 1 to 2 inches thick between the layers and on the outside. Heavily infested fruit had been placed in the center and at other locations in the crate prior to fumigation. Penetration into a 30-gallon open metal can filled with mangoes and into a bushel sack also appeared to be satisfactory. Complete mortality was also obtained in fruit cooled to 50° F. for 1 or 2 days before fumigation (air temperature 85°).

No definite indication of off-flavor or quality reduction was obtained in any of the fumigations at dosages from 2 to 6 ounces per 1000 cubic feet in taste tests by 10 to 12 people 3 to 5 days after fumigation. In a small-load test with a 12-ounce dosage one person indicated that the very delicate flavor of the D. B. Alphonse variety of mango had been affected. It is possible that the particular mango was not quite ripe for on another fruit of the same variety no effect could be determined in a taste test by four people. In many of the tests people favored the fumigated fruit.

In the large-load fumigations made on the Mayaguezano variety it was indicated that there would be some spoilage of ripe fruit over the 5-day period after fumigation, but similar losses occurred on the unfumigated ripe fruit. The spoilage was least in the green fruit, and this type will probably be the most practical to use in shipments.

SUMMARY.—At San Juan, Puerto Rico, investigations were made with ethylene dibromide as a fumigant for mangoes infested with fruit flies. Complete mortality of the larvae and pupae of the West Indian fruit fly, *Anastrepha mombinpraeoptans* Sein, in mangoes and of *A. suspensa* in almendra nuts was obtained with dosages of 2 to 6 ounces of ethylene dibromide per 1000 cubic feet in 2-hour fumigations at 85–87° F. Some larvae exposed to a 1-ounce dosage remained moribund for several days, an indication that this was near the lower limit of complete efficiency. Gas penetration into sacks,

open cans, and crates of commercially packed mangoes appeared satisfactory. The gas was also effective with fruit precooled to 50° F.

Complete mortality was also obtained in two large-load fumigations at 4- and 6-ounce dosages. A delayed kill was more evident at the lower dosage, so that the 6-ounce rate appears more practicable for large-scale use at temperatures near 85° F. Little detrimental effect on flavor of several varieties of mango could be detected at dosages of 2 to 6 ounces. Some spoilage occurred when commercially packed ripe fruit was held near 50° F. for 5 days after fumigation, to simulate conditions during the ship's voyage to New York. However, similar losses occurred on the untreated checks. The use of green fruit appears most practical for shipments.

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Effect of Husk Cover of Corn on Rice Weevil Damage in Alabama[1]

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The value of good husk cover of corn in preventing insect injury has been recognized for many years. Good husk cover has been widely recommended for reducing rice weevil injury to corn, both in the field (Hinds 1914; Wenholz 1917, 1927; Kyle 1918; Back 1919; Cartwright 1930, 1936; Veitch 1934; Mossop 1940) and in storage (Kyle 1918; Uichanco & Capco 1934).

The extent of weevil injury to corn, until the development of the acid fuchsin stain method (Frankenfeld 1948), was measured by counting either the number of weevils per ear or the number of emergence holes in the kernels. Since these methods did not include kernels into which eggs had been deposited and larvae were developing, they did not measure the exact amount of weevil damage. Research on the relationship of husk cover of corn to rice weevil damage, using the acid fuchin stain method for measuring weevil damage, was conducted in Alabama in 1949 and 1950. The results are reported in this paper.

PROCEDURE.—Table 1 gives the ratings for husk cover. The amount of the ear exposed was used as the main criterion for rating coverage. Very good husk cover was rated as 5 and very poor as 1 with intermediate ratings of 2, 3, and 4.

Husk cover ratings were made in 1949 on 29 varieties and hybrids of corn in a regular variety test conducted by the Department of Agronomy and Soils at the Plant Breeding Unit at Tallahassee. The varieties were grown in 2-row plots 50 feet long. They were replicated 4 times in randomized blocks. Husk cover ratings of ears were taken about 2 weeks before harvest on every fourth stalk in each replication.

The corn was harvested when mature, and one-half of each replication of each variety was shucked and shelled. After mixing, samples of approximately 500 kernels were taken, and the weevil damage was

[1] Part of the data included herein was taken from a thesis presented to the University of Illinois in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Table 1.—Ratings for husk coverage of corn ears.

RATING	DESCRIPTION
Very good—5	More than 2 inches of husk extend beyond tip of ear; tip of husk tightly closed; none of ear exposed.
Good—4	Less than 2 inches of husk extending beyond tip of ear and husk tightly closed; or, more than 2 inches of husk extending beyond tip of ear and husk not tightly closed; none of ear exposed.
Fair—3	Husk extending only to tip of the ear, or, if beyond, less than 2 inches and tip of husk not tightly closed.
Poor—2	Husk not extending beyond tip of ear; or, if so, tip of husk standing open; or, tip of ear otherwise exposed.
Very poor—1	More than 1 inch of ear extending beyond the husk, or ear otherwise badly exposed.

Table 2.—Relationship of husk cover of corn to rice weevil damage at harvest and after eight months of storage.

VARIETY	PER CENT DAMAGE AT HARVEST	HUSK COVER RATING	PER CENT DAMAGE AFTER 8 MO. OF STORAGE
Dixie 18	2.2	4.67	14.2
Dixie 11	3.5	4.06	42.5
La. 1031	2.8	3.94	22.2
La 521	3.3	3.91	41.0
Woods S-360	4.9	3.87	18.2
McCurdy 1010W	3.0	3.76	17.1
N.C. 27	4.6	3.75	21.7
McCurdy 1002	3.9	3.72	21.6
McCurdy 1001	5.5	3.59	28.4
Funks G-714	5.2	3.48	23.2
Paymaster	10.7	3.45	45.2
Tenn. 10	10.3	3.43	38.3
N.C. 26	8.2	3.43	29.8
Ga. 101	7.3	3.41	40.3
Funks G-737	4.0	3.36	23.9
Indian Chief	6.4	3.21	26.0
Mosby	16.4	3.20	55.5
Dixie 17	6.6	3.17	49.0
McCurdy 1005W	11.7	3.17	44.2
P.A.G. 630	5.8	3.14	47.8
Funks G-717	7.9	3.09	26.8
Tenn. 602	5.4	3.00	24.6
Dixie 44	11.0	2.84	31.4
N.C. 1032	5.2	2.76	29.0
P.A.G. 631W	18.6	2.66	56.8
P.A.G. 620	10.4	2.39	53.4
Funks G-711	17.1	2.07	62.6
P.A.G. 170	18.7	1.93	72.2
U.S. 13	26.1	1.81	81.9

determined by the acid fuchsin stain method. The other half of each replication was stored in the shuck without treatment. After 8 months of storage this corn was shucked and shelled, and the weevil damage was determined.

RESULTS.—The results of the studies are presented in table 2. Dixie 18 hybrid with a high husk cover rating of 4.67 had only 2.2 per cent of the kernels damaged at harvest. Similarly, Dixie 11 with a husk cover rating of 4.06 had only 3.6 percent weevil damage. U. S. 13 hybrid with a poor husk cover rating of 1.81 suffered 26.1 per cent weevil damage at harvest. P.A.G. 170 with a husk cover of 1.93 had 18.7 per cent damage at harvest. An analysis of variance of a simple linear regression calculated from these data shows a highly significant relationship between husk cover and weevil damage at harvest. The calculated F (Snedecor 1946) was 51.72; the tabular F for significance at the 1 per cent level was 7.68.

After 8 months of storage without treatment, the same relationship was present, although it was not as marked as at harvest. Dixie 18 with good husk cover had 14.2 per cent of the kernels damaged. U. S. 13 with poor husk cover had 81.9 per cent damage. However, the increase in damage in some of the intermediate corns was not directly proportionate to the husk cover rating.

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Termite Treatment with Aqueous Solution of Chlordane

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The soil around the foundation of a residence treated with one per cent solution of chlordane in September, 1947, was tested after the end of 4 years. Paralysis was more uniform in time, than at the end of 3 years. The toxicity appeared to be a little greater. Chlordane was not uniformly inserted about the foundation, and all eight samples could hardly have come from points of higher concentration. A difference in the condition of the termites is suggested.

Further improvements of the methods of testing were sought. It is evident that the controls without food do not usually live very much longer than some hardy individuals of the paralyzed specimens which sometimes show limb twitching for a week after loss of body control. A marked improvement in the control of moisture was made by maintaining it with a DeVilbis No. 182, quarter-ounce nasal atomizer. Fine droplets of water which struck the termite workers did them no harm. Five cc. stender dishes were used; larger ones could be used when the atomizer is employed. Some of the check soil was sterilized since a growth of fungus had made difficulties in former years. No fungus appeared in the controls of sterilized soil.

Tests with Lindane Vapor for Freeing Aircraft from Insects[1]

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The need for disinsectizing aircraft to prevent the spread of insects harmful to agriculture and public health has been recognized ever since airplanes have been making long-distance flights (Kisliuk 1929, Griffitts & Griffitts 1931). Early experiments on ways to kill insects in airplanes included the use of hydrocyanic acid and carboxide fumigant (a 10:90 mixture of ethylene oxide and carbon dioxide). In 1935 a nonflammable pyrethrum spray was introduced by Williams & Dreeson (1935), and an air atomizer for its proper application was perfected by Dunnahoo (1943).

Since 1942, when Sullivan *et al.* (1942) suggested the use of aerosols for controlling insects in aircraft, there has been a constant improvement in aerosol formulations (Fulton & Rohwer 1949, McBride *et al.* 1950, and Fales *et al.* 1951) and automatic equipment for dispensing them (Snow 1945, Yeomans *et al.* 1949).[2]

This paper reports tests with a promising method for killing insects in airplanes which utilizes the air-conditioning system to disperse the vapor from slightly volatile but highly effective insecticides such as lindane (Slade 1945, Fulton *et al.* 1950). Lindane has a vapor pressure of 9.4×10^{-6} mm. of mercury at 20° and 4.5×10^{-5} mm. at 30° C. (Balson 1947).

METHODS.—Four test flights were conducted in a five-passenger Cessna-195 airplane having a cabin capacity of 120 cubic feet.[1] The method used was to spray lindane on a fiberglas filter (Sullivan 1951) and then place it in the air-conditioning system. In practice 8.3 grams of lindane was sprayed on two 4 by 8 by 1-inch sections of the filter, which were then placed back to back and mounted to cover an outlet of the air-conditioning system. In flights 1 to 3 they were placed in a recirculating unit equipped with a 4-inch fan. In flight 4 outside air admitted through a forward cabin ventilator was passed

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 10–13, 1951.

[2] Also unpublished work by J. M. Hirst.

through the filters, which were mounted at the outlet. Both procedures caused the lindane vapor to be dispersed throughout the airplane at concentrations sufficient to kill some insects.

The plane was flown at an altitude of about 2000 feet at 150 mph., with the cabin temperature varying between 56° and 85° F. A test period of 20 or 30 minutes was used for the exposure of free-flying and caged flies, mosquitoes, and miscellaneous agricultural insects. They were then held for a 24-hour observation period.

RESULTS.—The results obtained for the four flights are given in table 1.

Table 1.—Effectiveness against insects of vapor from lindane applied on Fiberglas filters in the air-conditioning system of aircraft in flight.

FLIGHT	TEMPERATURE	EXPOSURE PERIOD	INSECT[1]	KNOCKDOWN	MORTALITY IN 24 HOURS
	°F.	*Minutes*		*Per Cent*	*Per Cent*
	Filter in inboard air-conditioning unit				
1	56–60	20	*Musca domestica*	100	100
			Culex pipiens	100	100
			Aëdes aegypti	100	100
2	78–80	30	*M. domestica*		
			Caged	90+	100
			Free-flying	95+	—
			A. aegypti		
			Caged	100	100
			Free-flying	100	—
3	80–85	30	*M. domestica*		
			Caged	90+	93
			Free-flying	90+	100
			A. aegypti		
			Caged	90+	100
			Free-flying	90+	100
			Miscellaneous agricultural	0	0
	Filter in ventilator admitting air from outside				
4	78–80	20	*M. domestica*	—	76
			A. aegypti	—	100

[1] All insects in flights 1 and 4 and the agricultural insects in flight 3 were caged.

A 20- or 30-minute exposure to the lindane vapor was sufficient to kill 76 to 100 per cent of the house flies and 100 per cent of the mosquitoes. Those insects killed were usually knocked down within an hour. There was little or no mortality of flies and mosquitoes used as checks. The agricultural insects however, were not visibly affected.

DISCUSSION.—The ideal method for disinsectizing aircraft should be effective against insects and at the same time safe, clean, sure, easy to operate, automatic, and labor-saving. It should also be nonannoying to passengers and crew and acceptable to airline and military officials. The equipment used should be light in weight and the pesticide penetrating. Several of these requirements are fulfilled by the method described. It is simple and automatic, the equipment needed weighs only a few ounces, and the vapor has the penetrating properties of a fumigant, leaves no visible deposit, and is invisible to passengers.

Further tests are planned to determine whether this method is practical in large modern aircraft with complex air-conditioning systems. However, it would still be necessary to kill resistant agricultural insects with a pre-departure aerosol treatment. It is also emphasized that the effect of lindane vapor on humans has not yet been determined.

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Cabbage Seedpod Weevil Control with Parathion[1]

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The cabbage seedpod weevil, *Ceutorhynchus assimilis* (Payk.) has been established in Oregon since 1936. In the Willamette Valley it has never reached the high population rates reported as existing in the seed-growing areas near Mt. Vernon, Washington, in Idaho and probably in California. This is thought to be due to the prevalence of wild turnip *Brassica campestris*, and the high rate of parasitism.

[1] Published as Technical Paper No. 725 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

An attempt has been made during the past 3 years to correlate adult weevil populations in cabbage fields with the resultant per cent seed-loss caused by the larvae. Weevil populations were sampled by sweeping with an insect net, and seed-loss was estimated from an examination of pods collected shortly before harvest in July. Weevil numbers have ranged from 0.05 to about 3 per sweep and the resulting seed-losses from 0.25 to 16 per cent. It has been tentatively concluded that a weevil population of 0.4 per sweep, or greater, at full bloom time (mid-May) will result in from 10 to 16 per cent loss of the cabbage seed if no control measures are applied.

Benzene hexachloride was early found to be effective against the adult weevils and has been used generally in crucifer seed-growing areas. In 1948 a preliminary test with 2 per cent parathion dust showed this material to be more promising than benzene hexachloride against the adult weevils. Furthermore, an observation in the insectary with dusted sprigs of wild turnip pods indicated that both of these materials were affecting the weevil grubs within the pods. Parathion appeared to be particularly lethal to the larvae—allowing none to emerge from the pods.

On the basis of this observation, half acre plots of seed cabbage were treated by the use of knapsack dusters with 2 per cent parathion in 1949 and in 1950. The 1949 field received two applications in May (the first being washed off by rain within 24 hours). The 1950 field was given only one application in mid-June, after the blooming was complete. Seed-loss for the 1949 field was estimated at about 1 per cent, and that of the late-treated 1950 field at 1.3 per cent. Loss from both of these fields should have been at least 10 per cent, since the weevil populations at full-bloom ranged from 0.44 to 2.1 weevils per sweep.

Additional insectary tests have been made of the effects of parathion dust on weevil grubs within crucifer seedpods. Turnip sprigs, known to have a fairly high per cent of infested pods, were dusted with 2 per cent parathion. These treated sprigs and untreated checks were placed in individual water vials in the insectary. Pods from the sprigs were then dissected and examined for larvae and eggs at 2, 5, and 7 day intervals. 100 per cent of the larvae were found to be alive in the check pods in the first two examinations, and 96 per cent alive on the seventh day. In the treated pods, 70 per cent were found to be moribund on the 2nd day, 80 per cent were dead on the fifth day, and 96 per cent dead on the seventh day. Even the eggs appeared to be affected, although it was difficult to determine whether an egg were dead or not. The egg ratios in treated and check pods on the second, fifth and seventh days were 1.4 to 1, 3 to 1 and 13 to 1, respectively. This suggests that parathion is either toxic to the eggs or greatly delays their hatching.

Sprigs of cabbage pods (which develop later than turnips) were treated in a similar manner, but examinations for larvae were made only on the seventh day. Pods from each of five sprigs were examined until five larvae, dead or alive, had been found. It is usual for a pod to contain only one larva under Willamette Valley conditions. Control of the grubs was complete in this case—there being 100 per cent dead in the treated and 100 per cent alive in the check pods.

One more test was made on the turnips to determine the effects of parathion under field conditions. Five 50-foot rows were dusted at the rate of 40 pounds of 2 per cent parathion per acre with a knapsack duster after the blooming period was complete. One week later sprigs of these treated plants were selected at random and the pods examined. The control obtained was not as good after this length of time as that found in the insectary tests, there being only 64 per cent mortality in the treated pods and 16 per cent in the untreated checks. Parasitism (principally by *Trichomalus fasciatus*) had shown up by this time, however, at the rate of 20 per cent of the check larvae and 48 per cent of the grubs in the treated pods. The difference in rate of parasitism has not been explained, but it may be due to sampling error. Possible effects of parathion on parasitic larvae has not been determined yet.

The dusting of cabbage or other cruciferous crops during the bloom period is deleterious to honey bees, which are the principal pollinators. These results indicate that late applications (after bloom) of 2 per cent parathion may give satisfactory reduction of seed-loss under Willamette Valley conditions without seriously affecting honey bee populations. Parathion has the advantage of not contaminating the soil for food crops, as is the case with benzene hexachloride, but the hazards involving its use are well established.

Treatment of Peach Nursery Stock to Prevent Infestation by Peach Tree Borer

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Although the peach tree borer, *Sanninoidea exitiosa* (Say), can be controlled after it gains entrance into nursery stock, nurserymen are very much in need of a way to prevent nursery stock from becoming infested. Stock severely injured or girdled by the borer cannot be offered for sale. Consequently, experiments to develop a treatment that will prevent infestation of nursery stock by this borer were conducted at Zebulon, Georgia, in 1950.

The nursery trees used for these experiments were developed from dormant buds of a number of varieties on one-year-old stock. Each treatment and an untreated check were replicated five times on rows of nursery stock each 50 yards long. There was no preparation of the soil before treatment, except to remove grass and weeds, and the trees were given no attention before or after treatment. The materials were applied as sprays to the trunks of the nursery stock with a 3-nozzle spray broom containing No. 2 disks supplied from a power sprayer operated at a pressure of 300 to 350 pounds per square inch. All treated plots were sprayed on August 2, September 1, and October 2. The stock was dug on October 30 and 31. Each nursery tree was examined when dug to determine the number infested with the peach tree borer.

The results are summarized below:

TREATMENT (8 POUNDS PER 100 GALLONS)	TREES EXAMINED	TREES INFESTED
BHC (6% gamma isomer wettable powder)	1087	5.0%
DDT (50% wettable powder)	1000	3.0
Check, untreated	1090	22.6

Benzene Hexachloride and DDT Sprays for Peach Tree Borer Control

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Experiments with BHC and DDT applied as sprays for control of the peach tree borer, *Sanninoidea exitiosa* (Say), were continued at Fort Valley, Georgia, during 1949 and 1950. The sprays contained 8 pounds of wettable powders containing either 6 per cent of the gamma isomer or 50 per cent of DDT per 100 gallons. Two or three applications were made in 1949—on August 15–16 and September 1 or on August 15–16, September 1, and September 15—and three applications were made in 1950—on August 1, September 5–11 and October 10. From 16 to 25 trees were used for each test. They were examined for borer infestation between May 9 and 24, 1950, and between April 23 and May 10, 1951. The results follow:

Orchard No.	Age of Trees (Years)	Average Number of Live Borers per Tree Treated with— BHC 2 Sprays	BHC 3 Sprays	DDT 2 Sprays	DDT 3 Sprays	Untreated Check
1949–50						
1	5	1.1	0.9	1.9	0.6	8.8
2	6	13.2	6.4	10.2	11.1	20.9
3	6	.1	.0	.4	.7	6.1
1950–51						
1	4		.1		.0	3.8
2	6		1.1		1.3	11.5
3	7		.6		.4	6.6
4	7		.8		.5	6.7

[1] Julius P. Hollon assisted with the experiments reported in this paper.

Further Studies of Dispersion of Flies Tagged with Radioactive Phosphoric Acid[1,2]

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In a previous experiment radioactive phosphorus was found to be a satisfactory means of tagging flies for use in studies of their flight habits (Lindquist *et al.* 1951). In order to obtain more information on the flight habits of flies, another experiment with radioactive flies was conducted in August 1951. It was carried out near Corvallis, Oregon, in the same area where the earlier studies were made.

EXPERIMENTAL PROCEDURE.—The flies were reared in the laboratory and when 2 to 9 days of age were fed radioactive phosphoric acid at the rate of approximately 20 μc (microcuries) per 1000 insects. This isotope was added to about 12 to 15 ml. of water containg some sugar. On August 12, after sundown, 60,000 *Phormia regina* (Meig.), 54,000 *Musca domestica* (L.), and 700 *Phaenicia* sp. flies that had become radioactive were released in the center of a study area. Just before release samples of flies taken from the various cages showed radioactivity ranging from 200 to 8000 cpm (counts per minute) per insect. All testing for radioactivity was made with a standard laboratory monitor equipped with a thin-walled Geiger-Mueller tube.

Standard screen-wire traps (Bishopp 1930) were distributed throughout the area—24 within a circle having a radius of 4 miles and 16 from 8 to 16.5 miles from the center of this circle, 10 in a northerly and 6 in a southerly direction. On the second day after the flies were released 2 traps from the north and 2 from the south were moved, 2 of them to a point 20 miles, 1 at 24 miles, and 1 at 28 miles to the south of the release point. All except 3 traps were set in what appeared to be favorable locations on farmsteads.

Each trap contained bait consisting of 1 pound of decomposed liver plus 1 quart of fermented blackstrap molasses in water.

During the period of study the prevailing winds were from the northwest and the mean daily temperature was 66.4° F. with a mean maximum of 84° and a mean minimum of 49°.

Table 1.—Total numbers of tagged *Phormia* and *Musca* flies taken in two to six collections from traps at different distances from the release point.

Inner Area: Miles and Direction from Release Point	*Phormia*	*Musca*	Outer Area: Miles and Direction from Release Point	*Phormia*	*Musca*
0.5 E	347	1216	8 S	5[1]	4
1 S	144	110	NE	6	0
N	27	1	10 NE	14	0
NW	36	9	11 NE	0[1]	0
2 S	18	1	NE	13	0
SE	70	20	12 S	16[1]	0
E	56	9	13 NW	4	0
NW	60	25	NE	3	0
2.5 SW	10	0	14 NE	0[1]	0
3 S	10	0	15 S	17	1
SE	79	15	SE	10	0
N	36	5	SE	18	0
NE	50	8	NW	0	0
NE	23	5	15.5 NE	22	0
E	26	1	16 NE	1	0
NW	2	0	16.5 SE	7	0
W	22	5	20 S	11	0
3.5 E	216	6	S	11	1
SE	95	8	24 SE	3	0
N	44	0	28 SE	1	0
NE	28	2			
4 S	5	0			
SE	24	11			
W	16	30			

[1] Traps moved to 20 to 28 miles 2 days after release.

RESULTS.—*Phormia regina:* Twenty-four hours after the release, flies were collected from the traps within the 4-mile radius but not from those 8 miles or more from the release point. Tagged *Phormia* flies were recovered from most of these traps. Collections after 48 hours showed *Phormia* in all but 5 of the 24 inner traps and all but 7 of the more distant traps. They were taken in traps 16.5 miles to the southeast and 15.5 miles to the northeast.

The collection 13 days after release, covering a 7-day trapping period, showed a total of 27 tagged *Phormia* flies in the traps 17 to 28 miles out. One

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 10–13, 1951.

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fly was taken in the 28-mile trap, which appears to represent the longest flight recorded for this species. Six tagged flies were taken on September 6, the last time collections were made. Of the total number of *Phormia* flies caught 52 per cent were females. Forty-five per cent of the flies taken in the distant traps were females, which demonstrates that both sexes have the capacity for long flight.

During the first few days most of the *Phormia* flies captured in the inner study area were in a southerly direction from the release point, but thereafter the population equalized. The 16 traps 8 miles or more away caught 99 flies and 63 north of the release point, or a total of 162 flies. The 24 traps within a 4-mile radius of the release point caught 1444 flies. This recovery was 2.64 per cent of the total number of flies released. The last tagged flies captured were about 24 days old.

At the time of release several thousand wild blow flies were trapped from within the area and dusted with yellow pigment. The pigment did not color the flies very well and it was difficult to recognize them in collections, but a few definitely colored ones were noted in the trap collections. One colored *Phormia* fly was taken 8 miles to the south, an indication that native flies will travel a considerable distance.

The summary data in table 1 show that 4 traps in the inner area caught 10 or less *Phormia* flies each and 9 distant traps each took 10 or more. No explanation can be given for the unequal numbers caught in different situations. The traps in the inner circle, excluding the 3 that took more than 100 *Phormia* each, captured an average of 31 tagged flies per trap. The number caught per trap in the outer area averaged 10, which indicates a remarkable recovery by 16 traps in an area of approximately 2413 square miles outside the inner circle. To have a distribution and coverage similar to that of the inner area, 1160 traps would have been required in the outer area. Should these traps have averaged 10 flies each, a total of 11,600 *Phormia* would have been caught.

Musca domestica: Tagged *Musca domestica* flies were caught in 15 of the 24 traps in the inner area 24 and 48 hours after their release. After that period the numbers caught declined rapidly, and none were taken after 12 days. Only 6 of these flies were captured beyond the inner circle, the farthermost point being 20 miles to the south. This is believed to constitute a new record for flight range of this species.

The trap ½ mile from the release point captured 81 per cent of the total *Musca* flies captured, and 67 per cent of these flies were caught during the first 24 hours. The other traps in the inner area captured an average of 22 flies each. With this trap included, the average number caught was 62 per trap.

Except in the ½ mile trap 91 *M. domestica* flies were caught toward the north and 189 toward the south, which indicates more movement down wind than for *Phormia*.

Of the total number of tagged *Musca* flies released, 2.78 per cent were recovered. Eighty per cent of the captured flies were females, and of the 6 taken 8 to 20 miles from the release point 5 were females. The last recovered fly was about 10 days old.

Phaenicia sp.: Only a limited number of tagged *Phaenicia* flies were released, but 25, or 3.57 per cent, of them were recovered, all in 9 of the 24 traps in the inner circle.

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Reduction of Wireworm Damage to Potatoes[1]

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Satisfactory control of *Agriotes mancus* Say, the wheat wireworm, and wireworms of the genus *Melanotus* infesting potato tubers has been difficult, particularly in new ground or where growers have not followed an alfalfa-rye-potato or similar rotation. At present, use of DD mixtures and ethylene dibromide as wireworm toxicants is sometimes recommended but cost and application methods

Table 1.—Wireworm injury to Chippewa potato tubers grown in soil receiving various insecticidal treatments. One hundred tubers per plot examined.

INSECTICIDE	LBS. PER ACRE	PER CENT WIREWORM INJURY
1. Aldrin	0.5	12
	1.5	4
	3.0	5
	6.0	0
2. Dieldrin	0.5	29
	1.5	3
	3.0	2
	6.0	0
3. EPN-300	4.0	1
	8.0	4
	16.0	0
4. Parathion	4.0	4
	8.0	0
	16.0	0
5. Lindane	0.5	15
	1.5	4
	3.0	3
	6.0	0
6. TM784[1]	200.0	9
	275.0	3
	350.0	6
	400.0	5
7. Chlordane (applied in fert.)	5.0	3.8 (400 tubers examined)
8. None		47
		42
		38
		15
		26
		22
	Average	31.7

[1] Test material 784, Matheson Chemical Corp.

have retarded the widespread use of these chemicals in Michigan.

The initial spectacular success of technical benzene hexachloride in controlling the wireworms on potatoes, followed by the completely nullifying after-effects of flavor tainting, has caused workers to move with extreme caution. Certainly these requirements must be satisfactorily met before recommendations can be made concerning use of synthetic organic insecticides in the soil:

1. Cost must be low and easy methods of application found.
2. Tubers must not be contaminated by the insecticide.
3. Insecticides or breakdown products must not taint tuber flavor or alter quality.

In addition, studies should be carried out which would throw light on the direct injury by the materials to the plant and the effect of the chemicals on beneficial soil organisms. At the low dosages with which wireworm control is indicated in Michigan soils, the factors of plant injury and influence on soil organisms could conceivably be avoided.

Parathion was selected for test during 1950 as a volatile material of relatively short residual action. The easiest safe way to apply the material was thought to be by spraying the surface of the soil, then cultivating the surface residue in to a depth of 4 inches. Hence a 13-acre sandy loam field newly planted to Irish Cobbler potatoes was treated with 4 lbs. of actual parathion per acre. The operators wore gas masks and protective clothing, and the entire operation consumed six hours. At harvest random samples of treated and untreated control areas revealed that 71 per cent of the untreated and 47.9 per cent of the treated tubers were wireworm-infested. The failure of this test could be blamed on low dosage or method of application, *i.e.*, losing material due to volatization of the residue before cultivation. No effect on tuber flavor was detected from this test.

In 1951, an adjacent field of randomized 0.01 acre blocks was treated by hand. Materials were diluted in pyrophyllite and shaken as a dust from a sack. The soil was of the same type as in 1950 and insecticides were cultivated in immediately following application to the 4-inch depth on already planted Chippewa seed pieces. Materials, dosages and injury to tubers at harvest is shown below.

Apparently satisfactory control of wireworms was accomplished by 1.5 pounds per acre of lindane, dieldrin and aldrin in this soil. While 4 pounds of parathion did not control wireworms when sprayed on the soil in 1950, the hand application followed by cultivation did effectively reduce the damage. Four pounds of EPN-300 also were effective. A commercial insecticide-fertilizer mixture of chlordane, prepared locally, applied at 5 lbs. per acre of chlordane controlled wireworms, as did an experimental material TM-784. Yield data were not taken. Observations of aerial growth and of tubers at harvest revealed no striking differences between treatments.

Representative tuber samples were selected and tested by the Department of Foods and Nutrition of Michigan State College. The results are set forth tabularly below.

In this test flavor and texture of all samples were scored acceptable. However, the flavor of tubers from 6 lbs. per acre aldrin plot and from one plot of 5 lbs. per acre chlordane treatment seemed to have a lower rating than the other treatments. The aldrin dosage may be excessive but the readings indicate a trend.

Table 2.—Quality of potato tubers tested with various insecticides. Maximum score 7.[1]

Amount of Insecticide per Acre	General Appearance	Color	Odor	Flavor	Texture	General Score
Lindane 6 lbs.	5.8	5.3	5.3	5.5	5.8	5.3
Aldrin 6 lbs.	5.3	5.0	5.7	4.0	5.3	4.7
Chlordane 5 lbs.	5.8	5.3	5.8	5.0	5.5	5.3
Chlordane 5 lbs.	5.0	5.7	5.0	4.7	5.0	4.7
TM-34 400 lbs.	5.0	5.0	6.0	5.3	5.3	5.0
EPN-300 16 lbs.	5.3	5.3	5.7	5.0	5.3	5.0
None	5.8	5.3	6.3	5.5	6.0	5.8
None	5.0	5.0	5.3	5.3	5.1	5.1

[1] All samples were scored acceptable.

The results of this work are encouraging in that a chemical of known short residual action, parathion, apparently gave control of wireworms. This material and EPN-300 would not leave chlorinated hydrocarbon residues in the soil to add to soil accumulations of DDT which is currently used in spray applications to the aerial portions of the plant. At present, a more satisfactory method of applying the material to the soil is to be desired. Often local fertilizer blenders do not have equipment suitable to handle the mixing of highly poisonous chemicals with a fertilizer safely. It is suggested that a granular dust or a pelleted formulation could be applied by a fertilizer or seed drill. This work is entirely experimental. Further studies on various soil types must be carried on. In addition, the possibility of tuber contamination must be thoroughly explored.

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Evaluation of Dusting Schedules for Control of Cotton Insects[1]

R. L. HANNA and J. C. GAINES, *Texas Agricultural Experiment Station*

A modified factorial design has been employed in a number of experiments in the cotton insect research program of the Texas Station. These experiments, reported by Gaines (1941) and Gaines & Dean (1948), have been used principally for evaluating insecticidal control programs which have included both contact and stomach poisons. Since the contact insecticides in these tests were applied early in the season and principally for fleahopper control, the same design was easily adapted to an evaluation of early and late season control combined with a comparison of three materials for boll weevil and bollworm control.

The plats in the experiment herein reported were arranged in randomized blocks. There were three blocks of 12 plats each. Each plat was 12 rows wide and of sufficient length to make 0.1 acre. Three plats in each block remained untreated. Six plats received early season applications of 20 per cent toxaphene-40 per cent sulphur and three of these received late season treatment while the other 3 did not. The three remaining plats in each block were given late season applications only. Materials compared in the late season treatments were 2.5 per cent

[1] Technical contribution no. 1572 of the Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Table 1.—The average thrips infestation, boll weevil infestation, bollworm injury, spider mite infestation and yield of seed cotton on a factorial experiment at College Station, Texas.

Treatments	Average Thrips per 20 Plants	Boll Weevil Punctured Squares	Boll-worm Injured Bolls	Spider Mites per 50 Ter-minals	Yield Har-vested 1st Picking	Average Yield per Acre
Early Treatment (18 Plats)	19.1	8.2%	4.5%	417	64.0%	1578
No Early Treatment (18 Plats)	74.2	7.8	5.0	409	54.0	1532
Late Treatment (18 Plats)	50.3	9.4	3.1	256	59.0	1616
No Late Treatment (18 Plats)	41.3	7.2	5.7	532	59.1	1494
Early Treatment Only (9 Plats)	20.2	7.2	5.1	666	62.5	1561
Late Treatment Only (9 Plats)	82.5	5.3	2.3	343	52.7	1636
Early and Late Treatment (9 Plats)	18.0	7.5	3.9	168	65.5	1596
No Treatment (9 Plats)	65.9	5.8	5.4	397	55.3	1427
Aldrin-DDT & Early Toxaphene (3 Plats)	16.7	12.4	3.8	121	66.6	1512
Aldrin-DDT Late Only (3 Plats)	111.4	7.2	3.0	230	50.2	1625
Dieldrin-DDT & Early Toxaphene (3 Plats)	13.5	9.6	4.7	220	68.2	1585
Dieldrin-DDT & Late Only (3 Plats)	70.8	7.2	2.2	496	48.7	1728
Toxaphene Early & Late (3 Plats)	23.9	9.2	3.3	162	62.0	1690
Toxaphene Late Only (3 Plats)	65.2	10.8	1.7	304	59.8	1555

aldrin-5 per cent DDT-40 per cent sulphur, 2.5 per cent dieldrin-5 per cent DDT-40 per cent sulphur and 20 per cent toxaphene-40 per cent sulphur. Five early season applications were made from May 5 to June 7 at an average rate of 10 pounds of dust per acre. Three late season applications were made from July 12 to July 23 at an average rate of 15 pounds per acre. The cotton was harvested in two pickings, August 7 and September 11.

This type of design afforded a number of comparisons as shown in table 1 with sufficient replication for valid statistical tests of significance. Thrips control was adequate on all plats which were treated early in the season. The boll weevil, *Anthonomus grandis* Boh., infestation remained well below damaging numbers for the entire period. The bollworm, *Heliothis armigera* (Hbn.), infestation was not severe but was definitely lower on those plats which received late season treatment. The sulphur present in all formulations prevented a damaging increase of spider mites, *Septanychus texazona* McG. Those plats which received both early and late season applications had only one-fourth as many spider mites as the plats which received only the early treatments. The check plats and those plats which received late treatment only had medium infestations of mites.

There was no significant difference in the total yield between any two treatments or treatment combinations. This was probably due to extremely dry, hot weather and light weevil and bollworm damage. However, a significantly higher percentage of the total yield was harvested during the first picking from those plats which received early treatment. This hastening of the harvest may have been due principally to early season control of thrips.

Literature Cited

Gaines, J. C. 1941. A factorial experiment comparing insecticides for control of cotton insects. Jour. Econ. Ent. **34**(4): 512.

Gaines, J. C. and H. A. Dean. 1948. Tests of insecticides for the control of several cotton insects. Jour. Econ. Ent. **41**(4): 548.

PROCEEDINGS OF THE TWENTY-THIRD ANNUAL MEETING

EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Hotel New Yorker, New York City

November 15 and 16, 1951

The Twenty-Third Annual Meeting of the Eastern Branch, A.A.E.E., was called to order by the Chairman, F. H. Lathrop, at 9:45 A.M. November 15 in the Hotel New Yorker, New York City. During the ensuing two days the Chairman presided over the presentation and discussion of 35 papers. On the second day, President Roy E. Campbell of the parent association extended greetings to those assembled and invited all to attend the Sixty-Third Annual Meeting of the American Association of Economic Entomologists to be held in Cincinnati, Ohio, December 10–13, 1951.

At the preliminary business meeting the first day, the report of the Secretary-Treasurer was given and financial statement presented was referred to the Auditing Committee. Chairman Lathrop also appointed the following committees:

Nominations: M. L. BOBB, F. L. GAMBRELL, J. L. HORSFALL

Auditing: J. G. CONKLIN, M. P. JONES

Resolutions: E. H. WHEELER, A. M. WOODSIDE, P. J. CHAPMAN

REPORT OF THE SECRETARY-TREASURER

Notices of the Twenty-Third Annual Meeting to be held in the Hotel New Yorker were mailed to about 800 members of the parent association residing in the Eastern Branch territory the last week in September. The notice, calling attention to the time and place of the meeting and soliciting paper titles, brought forth a gratifying response of 35 paper titles. This was seven less than the year before due no doubt in part to the fact that the parent association was meeting in nearby Cincinnati a month later. The 35 papers were arranged in a 2 day program which was printed and copies mailed to about 900 names on the Eastern Branch list about 10 days before the meeting. Registration and membership dues for 1950–51 amounted to $640.00 which represents a $202.00 gain over the amount reported for 1949–50.

At the final business session on November 16, 1951, the following regular committee reports were submitted, discussed and voted that they be accepted.

REPORT OF THE RESOLUTIONS COMMITTEE

(1) Whereas, since our last meeting death has taken from our midst several of our distinguished members, namely, E. F. Phillips, William H. White, and S. A. Rohwer, be it resolved that our sense of loss in their passing be recorded in the minutes of this meeting.

(2) Whereas, the chairman of the Branch, Dr. Frank L. Lathrop, has conducted these sessions in a dignified, faithful and efficient manner and has greatly added to the value and interest of the program through calling for questions and encouraging discussions, be it resolved that the appreciation of all of the members of the Eastern Branch be extended to him.

(3) Whereas, the president of our parent organization, Mr. Roy E. Campbell, has honored us by coming from California to meet with and address us, be it resolved that we extend our appreciation and special thanks to him for his interest.

(4) Whereas, through the cooperation and fine attention to our needs, the Hotel New Yorker has contributed greatly to the enjoyment and success of our meeting this year, be it resolved that the management of the hotel be complimented and thanked for its efforts.

(5) Whereas, the Congress of the United States is currently giving consideration to the reorganization of the United States Department of Agriculture including the Bureau of Entomology and Plant Quarantine wherein the Bureau might lose its identity, *and whereas* it is the strong belief of the members of the Eastern Branch that the contemplated changes would result in a loss of over-all effectiveness in the work now done by the Bureau and would deprive the entomological profession of a national leadership which has been provided by the Bureau in its coordinated program of research, regulation and control operations, *be it therefore resolved* that the Eastern Branch go on record as being definitely opposed to the dissolution of the Bureau as such or to a loss of any of its present functions. *And be it further resolved* that a copy of this resolution be sent to the Secretary of Agriculture and to the Secretary of the American Association of Economic Entomologists.

Respectfully submitted
E. H. WHEELER
A. M. WOODSIDE
P. J. CHAPMAN, *Chairman*

REPORT OF THE AUDITING COMMITTEE

Your Auditing Committee has examined the financial statement, books and records of the Secretary-Treasurer (Dr. B. F. Driggers) and find them correct and in good order.

J. G. CONKLIN
M. P. JONES

REPORT OF THE NOMINATING COMMITTEE

Your committee proposes the following names to serve as officers of the Eastern Branch in 1952:

For *Chairman:* FLOYD F. SMITH

For *Vice-Chairman:* J. P. CHAPMAN

M. L. BOBB
F. L. GAMBRELL
J. L. HORSFALL

FINANCIAL STATEMENT

Balance on hand, November 15, 1950			$4,620.56
RECEIPTS			
Dues for 1950–1951—November 1950 meeting		$ 422.00	
Dues for 1951–1952		142.00	$ 564.00
Receipts for *Entoma*			300.00
Total Receipts			$5,484.56
DISBURSEMENTS			
News Reel Laboratory—Projection Equipment		$ 65.00	
Honorarium to Mrs. R. L. Busbey	$100.00		
Payment to Editor of *Entoma* (5% Gross Business)	350.00		
		450.00	
Payment to Secretary-Treasurer 1951		200.00	
Expenses of Secretary-Treasurer—22nd Annual Meeting		15.40	
Clerical Expenses			
Eastern Branch		57.50	
Entoma		38.00	
Postage and Stamped Envelopes			
Eastern Branch		58.92	
Printer			
Eastern Branch—Programs 1950 Meeting		37.50	
Double payment of dues		10.00	
Total Disbursements			932.32
Balance on hand, November 13, 1951			$4,552.24
Distributed as follows:			
Checking Account, the Union National Bank and Trust Company, Mount Holly, N. J.		$4,550.64	
Less Outstanding Check: 11/13/51—Edith B. Fagan		36.40	
		$4,514.24	
Cash on hand in office		38.00	
			$4,552.24

BYRLEY F. DRIGGERS,
Secretary-Treasurer

REPORT OF THE COMMITTEE ON INSECTICIDE INFORMATION

Your Committee on Insecticide Information appointed at our last meeting wishes to report as follows:

1. We consider from the tenor of the discussion which resulted in setting-up this committee and a review of the present developments relative to insecticides that the most urgent need is in the educational field.

2. In this field the pressing needs are (a) to inform the public of the great good that has been accomplished through the use of insecticides, and (b) how to use insecticides safely.

3. The committee feels that attention of the public needs to be directed to the benefits that have resulted from the use of insecticides to offset the criticism, often unjust, that has been made of entomologists, manufacturers and users of such materials, also to prevent the adoption of unnecessarily restrictive laws and regulations.

4. The committee believes that every entomologist recognizes that there are hazards connected with the use of insecticides and conscientiously guides the public to avoid those hazards. It appears doubtful, however, if all entomologists have given sufficient thought to adverse effects that may result from the improper use of certain insecticides and have stressed necessary precautions.

5. The committee also believes that certain crusaders against insecticides have by their extreme and often totally unfounded statements done much harm to the best interests of the people of this country and the world.

6. A canvass of the official entomologists of this country has been made to determine (a) whether they are putting out information on the benefits gained from insecticides. (b) If information on the safe use of insecticides is being presented to the public. (c) How such information is made available to the public. (d) If any adverse effects have been recorded in their work territory from improper use of insecticides. (2) If any state laws or regulations have been passed recently controlling the use of pesticides. (f) Plans for further educational work.

A considerable percentage of those to whom the inquiry was sent have responded and we feel that after the replies are all in and the information tabulated that it will be of much value in suggesting further action.

The replies show that practically all official entomologists are setting forth precautions in the use of highly toxic insecticides but some are not sufficiently emphasizing precautions to prevent residues on food crops and to avoid possible injury to beneficial insects and wild life. Much excellent information on how to use parathion safely has been distributed by industry, grower's organizations and by a number of entomologists.

Relatively little effort has been expended in determining losses chargeable to various insect pests.

Very few entomologists have publicized advantages gained from insecticide use except to give gains in yields in experiments and these data are usually found in more or less technical articles not intended for general reading.

Industry has published much information on increased yields secured from insecticide use but a considerable proportion is directed to those who make recommendations and to dealers rather than to the general public.

The committee recommends:

1. That efforts be made to gather concrete evidence on losses caused by various insects.

2. That schools for commercial insecticide applicators and pest control operators be encouraged.

3. That entomologists develop closer contact with economic poison control officials and health authorities.

4. That efforts be put forth to gather full information on reported cases of insecticide poisoning in man and animals, also on reported cases of crop injury and off-flavor.

5. That encouragement be lent to the adoption of State laws similar to the so-called model law relating to custom application of insecticides, fungicides and herbicides, prepared by various governmental and other agencies.

6. That efforts be made to increase toxicological research on effective insecticides.

7. That the importance of and specific methods of analysis of insecticide residues be stressed.

8. That the entomologists pay greater attention to precautions in recommendations for the use of insecticides.

9. That the safe and effective use of insecticides be brought to the public through all available publicity channels.

10. Your committee feels that there is much urgently needed work in this field on a national rather than a regional basis and recommends that it be continued and also that this report be brought to the attention of the Executive Committee of the A.A.E.E. with the recommendation that it set up a similar committee. It further recommends that in the event this action is taken by the parent association this committee of the Eastern Branch be dissolved.

ALBERT HARTZELL
BAILEY B. PEPPER
J. L. HORSFALL
C. E. PALM
F. C. BISHOPP, *Chairman*

In the discussion of the foregoing report, Dr. B. B Pepper moved, it was seconded and passed that the Secretary be instructed to forward a copy of the report to the Executive Committee of the parent association calling attention to the report and to the suggestion that a similar committee be appointed to act on a national scale. This was subsequently done before the meeting in December in Cincinnati, Ohio.

Under "New Business" Dr. J. G. Matthysse made the following motion:

"I move that a committee be appointed to investigate the desirability of changing part or all of the Eastern Branch program from a paper reading session to topic discussion type sessions."

After some discussion the motion was approved and Chairman Floyd Smith subsequently appointed the following to serve on this committee.

BAILEY B. PEPPER (Teaching)—*Chairman*
H. H. RICHARDSON (BEPQ)
H. H. SCHWARDT (Experiment Station)
H. G. WALKER (Industry)
E. H. WHEELER (Extension)

At the end of the paper reading session ony November 16th, the meeting adjourned with the announcement that the 1952 meeting was scheduled for Baltimore some time in November.

MEMBERS AND GUESTS REGISTERED AT THE TWENTY-THIRD ANNUAL MEETING, EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS, NOVEMBER 15 AND 16, 1951

Abrams, Louis
Adams, J. A.
Adams, Lloyd
Alessandrini, M. E.
Alexander, C. C.
Anderson, M. L.

Back, R. C.
Badertscher, A. E.
Baldwin, W. F.
Barker, J. S.
Barron, F. R.
Beard, R. L.
Becker, William B.
Bennett, H. E.
Berry, Robert
Bishopp, F. C.
Bissell, T. L.
Bobb, M. L.
Brandes, Gordon
Brann, J. L.
Bulger, J. W.
Burgess, E. D.
Bussart, J. Everett

Campbell, Roy
Cantelo, William W.
Chapman, P. J.
Clement, R. L.
Clunan, F.
Cohill, Roger W.
Compton, C. C.
Conklin, J. G.
Connell, W. A.
Connola, Donald P.
Cory, E. N.
Cox, J. A.
Craig, F. Waldo

Darley, M. M.
Davis, A. C.
Dewey, J. E.
Dimond, John
Dirks, Charles O.
Ditman, L. P.
Dohanian, S. M.
Donohoe, H. C.
Dorland, Wayne
Dorward, Kelvin

Driggers, B. F.
Duda, E. J.
Dunn, Henry A.
Dustan, G. G.
Dye, H. W.

Eddy, C. O.
Elmer, H.
Emerson, F. H.
Evans, J. A.

Filmer, R. S.
Fletcher, Fred
Frost, S. W.

Galloway, A. L.
Gambrell, F. L.
Garman, Philip
Gesell, S. E.
Gilbert, Engel
Ginsburg, Joseph M.
Giorgi, Anthony
Girard, Theodore
Glass, E. H.

Gleissner, Bruce D.
Goble, H. W.
Goodwin, W. J.
Gould, E.
Graham, Castillo
Granett, Philip
Grayson, J. M.
Greenwald, Margaret
Greenwood, D. E.

Hadjinicolaou, John
Hamilton, Clyde C.
Hamman, R. E.
Hammer, O. H.
Hanna, R. B.
Hansens, E. J.
Hart, William
Hartley, Richard D.
Hartzell, Albert
Haubein, A. H.
Hawkins, John
Haynes, H. L.
Heal, R. E.
Henneberry, Thomas V.

Hilchey, J. D.
Holden, K. R.
Horsfall, J. L.
House, H. L.
Hovey, C. L.
Huckett, H. C.
Huffington, Jesse M.

Incho, Eileen J.
Incho, Harry H.

James, M. P.
James, W. Scott
Janes, M. P.
Jarnagin, W. M.
Jennings, C. C.
Johnson, Gerald A.
Johnson, J. P.
Johnson, Roger B.

Kelsey, Lewis
Kenaga, Eugene
Kirchberg, E. W.
Knipe, Fred W.
Kriner, Ray R.
Kring, J. B.
Knutson, Herbert

Langford, G. S.
Lathrop, F. H.
Larson, N. P.
Leiby, R. W.
Lembach, John
Lepore, A.
Lienk, S. E.
Livingston, A. M.
Long, John C.

MacCreary, Donald
Macdonald, Bruce
Maddrey, J. B.
Majure, W. J.
Makmut, Karman
Malcolm, D. M.
Mathewson, John A.
Matthysse, John
Mayner, J. M.
McLeod, W. S.
Menusan, Henry
Miller, A. C.
Miller, Richard
Miller, Loze
Mills, Jr. H. O.
Mitlin, Normon
Mueller, Philip

Naegele, John
Nash, Kenneth B.
Nelson, Franklin C.
Nelson, R. W.
Nolan, K. G.

Parr, T.
Pass, H. A.
Payne, Nellie M.
Pechuman, L. L.
Pepper, Bailey B.
Pepper, J. O.
Persechino, Dante
Peterson, P. D.
Phillips, G. L.
Pierpont, R. L.
Piquett, P. G.
Porter, B. A.
Porter, Richard P.

Potts, S. F.
Pyenson, L.

Ratledge, Edward L.
Reed, T. W.
Rex, E. G.
Richardson, Henry H.
Richmond, Roy G.
Rife, Harold
Roark, R. C.
Roe, Jim
Roth, R. W.
Rowe, Phillip

Schmidt, B. G.
Schumaker, George A.
Scoggin, John T.
Scott, R. C.
Shands, W. A.
Sharp, S. S.
Siegler, E. H.
Simches, George
Simpson, G. W.
Sloan, M. J.
Smith, Clyde F.
Smith, C. L.
Smith, Floyd F.
Snyder, Fred M.
Soraci, F. A.
Spear, Philip J.
Spyhalski, Edward
Starnes, E.
Starnes, O.
Starr, Donald S.
Steiner, H. M.
Stevens, J. E.
Stokes, R. L.
Swenson, K. G.

TaqeAhsan, S. M.
Taschenberg, E. F.
Tashiro, H.
Tate, H. Douglass
Thompson, Hugh
Thompson, Robert K.
Tidwell, C. H.
Toczydlowski, Albert H.
Turner, Neely

Udine, E. J.
Underhill, G. W.

Vance, Arlo M.
Vandenberg, G. B.
Van Geluwe, John

Walker, Harry G.
Wallace, Philip P.
Wallace, Robert
Washburn, Lloyd
Watson, Jack
West, R. W.
Wheeler, E. H.
Wigley, R. S.
Willey, C. R.
Williams, A.
Williams, A. T.
Woodbury, E. N.
Woodside, A. M.

Yates, Richard
Young, Jr. V. H.

Zappe, M. P.
Zukel, John

HANDBOOK OF AGRICULTURAL PEST CONTROL, by Stanley F. Bailey and Leslie M. Smith. Industry Publications, Inc., New York. 1951. 191 pp. Price $3.25.

Pest control operators, orchardists, researchers, in fact everyone concerned with the application of insecticides, fungicides or weed killers will welcome the appearance of this handy little volume. The wide spread use of presently available effective and often dangerous pesticides demands speedy and accurate calculation of dilutions and dosages. The authors fully appreciate these needs and have brought together numerous facts and a series of tables that should save busy men much time and perhaps serious mistakes.

The agricultural chemicals treated are divided into seven functional categories: insecticides, fungicides, herbicides, plant hormones, nutrients, defoliants and blossom thinners. Under these the materials are grouped according to their chemical nature. The authors have wisely simplified and syllabized the chemical names. They have also included a few trade names. Some users doubtless would have preferred the inclusion of full chemical names and more complete trade designations. The limitations of the last are obvious, however. It would have added to the utility of the list to have had included more of the experimental materials now coming on the market such as heptachlor and dilan. The omission of TDE as a coined name is regrettable since TDE is now widely used rather than DDD.

The chapter on physical and chemical properties carries tables on solubility, density, freezing point, and stability of many of the usual pesticides. Types and sizes of containers in which pesticides are packaged are set forth in chapter 4.

A chapter is devoted to fumigants with a table on physical constants, fields of use of some fumigants, and methods and formulas for computing volumes of building, tents, etc. Residues and toxicological hazards are covered briefly, also specifications for spray oils.

Application of sprays and dusts is treated in a practical way with tables on rates of delivery of various equipment, at various pressures and speeds of travel. One chapter is devoted to mosquito control with information on methods of applying larvicides and adulticides; one to a brief consideration of repellents, defoliants, and the treatment of livestock and wood. The chapter headed "Tables and Formulas" is crammed with information on methods of calculating dilutions, dosages, conversion of weights, measurements, temperatures, etc. Definitions of many terms used in pesticidal operations are given.

This volume contains so much information that complete indexing is difficult and in this respect there is room for improvement. It is our guess that men in charge of field operations and those conducting experimental work will refer to the many time-saving features in this valuable reference work that they will soon need no index. The authors are to be complimented on their foresight in assembling this information and making it available to others.

F. C. BISHOPP

THE ENTOMOLOGICAL SOCIETY OF PENNSYLVANIA MINUTES OF THE TWENTY-NINTH ANNUAL MEETING

The twenty-ninth annual meeting of the Entomological Society of Pennsylvania was held in the Bureau of Plant Industry, State Capitol, Harrisburg, Pennsylvania.

The meeting was opened at 1:45 P.M. by president Arthur Jeffrey.

During the business meeting, Benjamin L. Hadley was approved for membership and the following elected for offices in 1952:

President—MR. STANLEY GESELL
Vice President—DR. JAMES COX
Secretary—MR. E. J. UDINE

The following members and visitors were present:

H. A. Strohecker	Dean Asquith
Dr. S. W. Frost	Geo. B. Sleesman
E. M. Craighead	Harry S. Kirk
Dr. H. M. Steiner	J. O. Pepper
Dr. C. A. Thomas	M. P. Jones
N. C. Farr	Wm. Wheatfield
G. C. Lettie	Robert Troxel
Dr. H. Menusan, Jr.	Dr. T. L. Guyton
C. F. Campbell	A. R. Jeffrey
S. G. Gesell	Lorenzo B. Pryor
Dr. M. W. Eddy	E. J. Udine

Mr. M. P. Jones, the guest speaker, gave an interesting review of Extension Entomology in the United States from its inception to the present. He also gave one of the activities of his office, that of coordinating information for State Extension Entomologists. Mr. Jones told the story of the National Annual 4-H Club Entomology awards and the donor, the Hercules Powder Company. He concluded by discussing "How the Extension Entomologist Works" in a selected number of states showing the various methods by which this type of work is done.

In the panel discussion which followed, the following information of general interest was brought up:

Mr. Sleesman discussed the following insects as new to Pennsylvania:

a. A damp wood termite identified by Dr. T. S. Synder as *Zootermopsis angusticollis* (Hagen) found in a carload shipment of third grade Douglas fir from Oregon.
b. A scale from umbrella pine identified by Dr. Morrison as *Lepidosaphes newsteadi* (Sulc.) near Moylan, Pennsylvania.
c. A pit-making scale *Asterolecanium puteanum* (Russell) on American holly.

Dr. Guyton discussed oak wilt and stated that it had been found in seven Pennsylvania counties, namely: Allegheny, Greene, Huntington, Mifflin, Perry, Franklin, and Adams.

Mr. Farr and Mr. Lettie discussed outbreaks of the black vine weevil (*Brachyrhinus ovatus* (L)) in nurseries in western Pennsylvania. Mr. Farr also described an European earwig—*Forficula auricularia* (L.) outbreak in Erie County.

Mr. Craighead found two mimosa webworm—*Homadaula albizziae* (Clarke), infestations on honey locust in Adams County, and Mr. Pepper reported heavy defoliation by the same pest in York County.

Mr. Craighead also called attention to a snipe fly *Atherix variagata* (Walker), with a State Museum record of a single specimen, collected in abundance on Penns Creek in 1950. Clusters of egg masses as large as 1½ feet were noticed. Photographs of adults, egg laying and eggs were shown.

Mr. Pepper stated that the rhododendron tip midge *Giardomyia rhododendri* (Felt) had caused considerable loss in a nursery in York County.

Mr. Kirk verified the source of bee poisoning in 1950 as the honeydew of the tulip tree scale *Toumeyella lirodendri* (Monell) and that there was no recurrence in 1951.

Dr. Menusan discussed the garden centipede *Scutigerella immaculata* (Newp.) and the damage it does to potatoes in the southwestern part of the state.

Mr. Campbell stated that a new, but small, gypsy moth infestation was located outside the original area in Lackawanna County and plans were under way for control measures in the spring.

Mr. Udine discussed an outbreak of the strawberry root weevil *Brachyrhinus ovatus* (L.) in a nursery, causing $20,000 loss in hemlocks and red pine. He also discussed the apparent difficulty in controlling imported cabbage worm on cabbage because of the location of the pest in the openings at the base of the leaves.

The meeting adjourned at 5:15 P.M.

E. J. UDINE, *Secretary*

JULIUS HYMAN & COMPANY CHANGES OWNERSHIP

Julius Hyman & Company, an integral part of the recent progress in the insecticide field, has been purchased by Shell Chemical Corporation which has thus acquired exclusive rights to Aldrin and Dieldrin as well as such other insecticides as may have been controlled by the Hyman Company.

It is stated that the origination will be maintained intact and that sales and field service will be expanded and that research in progress will be continued.

No plans which Dr. Hyman may have made have been announced but entomologists may feel sure that he will not abandon his interest in the field of entomology or his long standing and deeply appreciated friendly attitude toward all those who have so greatly benefitted by the association in the past.

REPORT OF THE FIFTEENTH ANNUAL SPRING MEETING

GEORGIA ENTOMOLOGICAL SOCIETY

Abraham Baldwin College, Tifton, Ga.

March 9–10, 1951

The meeting was called to order at 1:30 P.M. on March 9, 1951, by President G. G. Rohwer. Mr. F. E. Allison, Chairman of the Committee on Local Arrangements, introduced Mr. George P. Donaldson, President of Abraham Baldwin College, who delivered an address of welcome.

The minutes of the last meeting and the report of the Secretary-Treasurer were approved as read. Mr. P. W. Fattig reported for the Insect Survey Committee a total of 13,505 species recorded for Georgia as compared with 10,401 from North Carolina. Of these, 4374 are Coleoptera, 2496 Diptera, 2388 Hymenoptera, 1390 Lepidoptera, 969 Homoptera, and 726 Hemiptera. He requested help from the members in assembling records of Georgia Orthoptera.

President Rohwer appointed the following Committees:

Nominating:	C. H. ALDEN, K. D. QUARTERMAN, O. I. SNAPP
Resolutions:	W. E. BLASINGAME, F. R. BLACKWELL
Auditing:	G. W. SWANK, H. R. DODGE
Insect Survey:	P. W. FATTIG, W. E. BLASINGAME, C. M. BECKHAM

It was moved, seconded, and approved that the Secretary should represent the Society before the AAEE; that particularly desirable speakers from outside Georgia be invited to attend and present papers; that Georgia representatives of the various industrial organizations concerned with entomology be invited to affiliate; that various interested entomologists from surrounding states be invited to attend the meetings and become members.

President Rohwer then read a telegram of best wishes from Vice-President Tom Gunn, on duty with the U. S. Navy, Patuxent, Maryland.

The first paper-reading session followed:

1. J. H. Rigsby, Ga. State Dept. of P.H., Cordele, discussed "Methods, Materials, and Equipment Used on Mosquito and Fly Control Programs." He pointed out that residual DDT sprays were applied for mosquito control to the interiors of homes in all malarious areas in 35 counties in 1946. Using a regulated-pressure spraying gear that could be refilled at any gasoline station, two men could treat 30 to 35 houses per day. Residual sprays for fly control were applied to barns at the owner's expense. A rosin sticker was added to such sprays. 0.25% Chlordane (1 gal./100 sq. ft.) was used for killing larvae, enormous numbers of which were found in rendering-plant refuse, piles of pimento waste and manure.

2. O. K. Fletcher, Ga. State Dept. of P.H., Albany, reported "The Results of Five Years of Mosquito and Fly Control in Columbus, Georgia." In 1946, the Columbus-Muscogee County Health Department initiated a program of insect control. DDT was applied to all accessible resting places and habitats of mosquitoes, flies, roaches, fleas, and bedbugs at regular intervals, supplemented by a program of larviciding and basic sanitation to eliminate breeding areas. The program was evaluated by biologists of the Georgia Department of Public Health.

Domestic mosquitoes were reduced to 30% of their former abundance as compared with Phenix City, Ala., where no control was practiced. A tremendous reduction in house flies was observed during the first two years of the program, but this became progressively less as flies developed resistance to DDT. Bedbugs were virtually eliminated during the first few weeks of the program. Fleas represented only a minor problem. Good roach control was effected in the initial stages of the program by the use of DDT and later by the use of Chlordane. Public reaction to the program was very favorable. The entire cost over a five year period was only 47½ cents per capita per year. The mosquito control which was effected is, alone, worth many times this low cost. This program demonstrated that it is economically and otherwise feasible for an organized government agency to participate in the field of pest control.

3. H. O. Lund, Univ. of Ga., Athens, presented a moving picture on "Fogging with DDT for the Control of Blackflies" with the Bell Aircraft helicopter. The picture showed the excellent coverage obtainable because of the great maneuverability of the helicopter.

4. Garth Spitler, BEPQ, Tifton, described the "Methods used in Conducting Experiments Concerning the Control of Stored Grain Pests." This included sanitary storage preceded by rapid mechanical drying and shelling—the cheapest bin being a 5 cubic foot masonite cylinder; fumigation with ethylene dichloride and/or dibromide carbon tetrachloride—carbon disulfide, methyl bromide, and chlorpicrin; dusting with toxaphene, DDT, Chlordane, and pyrethrins; residual treating of bins and bagging with DDT, TDE, Methoxychlor, and Chlordane.

5. D. W. LaHue, BEPQ, Tifton, discussed "Damage by Rice Reevils to Corn in Storage." He pointed out that an average of about 15% of the weight of corn in storage is lost due to weevil infestation. In some varieties as high as 70.3% of the kernels were infested within eight months.

6. M. R. Ozburn, BEPQ, Albany, gave a "Report on Pecan Insect Control being Conducted at the Albany, Ga., Pecan Laboratory." Main emphasis is now being placed on the pecan shuckworm and the pecan weevil. Most of the new organic insecticides are ineffective but jarring and the use of six pounds of wettable DDT per 100 gallons of water are effective against the pecan weevil. Parathion is effective against the black pecan aphid and mites.

7. O. I. Snapp, BEPQ, Fort Valley, explained the "Treatment Used in White-Fringed Beetle Quarantines." In large-plot experiments conducted in peach orchards at Fort Valley, Ga., in 1950, nearly perfect control was obtained at peach harvest from five applications of parathion, 3 pounds of 15% wettable powder per 100 gallons. Fairly good results were obtained with four applications of parathion or of chlordane, and with a split schedule of benzene

hexachloride and lead arsenate. The regular schedule of lead arsenate gave poor results, permitting 21% of the fruit to become wormy.

Parathion and benzene hexachloride gave much better control of the plum curculio in peach drops than did chlordane and lead arsenate. In experiments on single-tree plots parathion placed first among the materials tested in both series of field plots. Not a single infested peach was found on single-tree plots treated with dieldrin or a split schedule of parathion and EPN. Aldrin gave good control in these experiments, and methoxychlor showed promise.

In cage tests parathion, EPN, insecticide 4049, methoxychlor, aldrin, dieldrin, and chlordane were effective against both overwintered and new first-generation plum curculio adults. On a basis of equal gamma content, lindane was less effective than technical benzene hexachloride. Metacide gave good results, but dilan, insecticides 4124 and C-1014 were comparatively ineffective. The residual value of EPN was exceptional whereas that of dieldrin, methoxychlor, parathion, and chlordane was good.

The flavor of ripe fresh peaches was affected by benzene hexachloride and that of canned peaches by benzene hexachloride and lindane. Most of the new insecticides caused no injury to the fruit, leaves, budwood or any part of peach trees. Tetraethyl pyrophosphate fog caused heavy defoliation and some fruit injury.

8. G. R. Swank, BEPQ, Fort Valley, explained the "Treatments Used in White-Fringed Beetle Quarantine." He commented on colored slides, showing first a short series of life history stages of the white-fringed beetle. This was followed by illustrations of the equipment as used in white-fringed beetle quarantine for the following processes: barerooting; normal atmospheric pressure and vacuum fumigation of ornamental nursery plants; soil sterilization with straight methyl bromide and with methyl bromide in organic solution; piperonyl butoxide activated pyrethrum dilutions for in-the-row treatments of nursery plants; cleaning a peanut picker before leaving an infested field; and foliage and soil insecticide applications.

9. C. C. Fancher, BEPQ, Macon, summarized the "Status of White-Fringed Beetles in Georgia." He pointed out that there was a drop in new finds from 31% in 1940 to 18% in 1950. In 1950, infestations existed in 59 counties, nine of these being tentatively listed as inactive. These involved 37,450 acres in Georgia. 12,510 acres were treated this last year.

10. G. W. R. Davidson, BEPQ, Macon, discussed the "Effectiveness of DDT as a Soil Treatment against White-Fringed Beetle Larvae." DDT incorporated into the soil is an effective means of destroying white-fringed beetle larvae, particularly when they are in the younger stages of development. Field tests started in December 1946 in a heavily infested field located near Marshallville, Ga., showed that 11 pounds of DDT per acre greatly reduced, by the following May, the population of 132 larvae per sq. yd. which were present at time of treatment. Only two larvae were found in the field in the spring of 1948 and none have been found since, although infestation has persisted in adjacent non-treated land and beetles from these areas have each year moved onto the treated site.

The annual banquet was held at 7:30 P.M. at the Alpine Restaurant. The banquet was presented with the compliments of the California Spray Chemical Company. Mr. F. E. Allison, southeastern representative of the Corporation, made the arrangements and served as toastmaster. 76 members and guests attended. Entertainment was provided by a girl vocal quartet and a baritone soloist from the Abraham Baldwin College.

The Saturday meeting began with a short response by O. I. Snapp to the address of welcome presented by President Donaldson.

11. J. J. Paul, Univ. of Ga., Athens, discussed "Sanitation Problems in the Food Processing Industry." Modern concepts of sanitation require that foods be free not only of infectious micro-organisms but also of contamination by every sort of food-defiling organism or material. Sanitary manufacturing procedures require that periodical inspections be conducted of factory and employees by personnel trained in entomology and sanitation; that raw materials be examined macroscopically and microscopically at time of receipt and prior to use; that finished products be examined frequently by laboratory methods; and that appropriate remedial procedures be instituted to correct any faults appearing in the sanitation program.

12. W. F. Turner, BEPQ, Fort Valley, spoke on the "Vectors of Phony Peach Disease." Four species of Tettigellinae (Cicadellidae) have been proven as experimental vectors of phony peach. These are *Homalodisca triquetra*, *Incometopia undata*, *Cuerna costalis*, and *Graphocephala versuta*. Some tests have been made with two other species of the subfamily, but results have been negative to date.

Field tests with DDT for the control of the vectors were begun in 1947. Readings on these tests, in 1949, were definitely encouraging in two orchards. In both, the incidence of new cases of disease had increased appreciably in the check, while it had been held level in one sprayed block and had decreased in the other.

13. Glenn KenKnight, BPI, Fort Valley, outlined "Recent Advances in Research on the Phony Disease." Hutchins demonstrated that phony disease is a virus disease and discovered a chemical test that is a valuable aid in diagnosis. He obtained transmission regularly by root-piece grafts from phony to normal trees, but did not obtain transmission (1) by buds (without wood), (2) by top-chain grafts in which phony trees were united with normal trees by whip-and-tongue grafting of branches, (3) by piece-root grafts using scions from phony trees on root pieces from normal trees, nor (4) to small nursery trees attached by their tap roots to branches of phony trees. He concluded that the phony virus was not in the tops of peach trees and that it was confined to the xylem of peach roots. More recently, Hutchins, Cochran, Weinberger, and Turner showed that phony can be transmitted by scions from at least some parts of some peach tops, and Turner obtained transmission of phony from peach tops with several insect vectors. To explain the conflicting results, numerous theories and hypotheses have been proposed. Most of these are based on the premise that the virus is present in only occasional branches of a small proportion of phony trees. This premise appears to be false. Again top-chain grafts as used by Hutchins failed to transmit, probably because there is little or no movement of food materials through such a graft, but normal trees approach grafted to phony trees became phony in 27 out of 27 cases. Peach seedlings attached by their tap roots to stumps of phony trees and forced as suckers became phony as demonstrated by transmission to other test trees. When scions from phony trees were

grafted on the stumps of decapitated nursery trees, a considerable proportion of the latter became phony and there was no relation between the per cent transmission and the diameter of the scion, or whether or not the scion had been exposed to the sun in its position on the source tree. Finally, a large majority of peach trees propagated from cuttings from phony trees are phony by the chemical test.

15. W. E. Towson, Univ. of Ga., Athens, described his studies in "Distinguishing Two Pairs of Closely Related Species of Cerambycidae." (1) *Typocerus velutinus* (Olivier) and *Monochamus titillator* (Fabricius) were studied to determine specific differences. Specific determination of an adult of either species of either pair is very difficult unless a representative of the other species of the pair is present for comparison because the external morphological differences are qualitative. When the aedeagus of the various species was extracted and studied, easily-seen and constant differences were found which greatly facilitated specific determination.

16. W. E. Blasingame, State Dept. of Entomology, Atlanta, gave a "Summary of Japanese Beetle Trap-Scouting and Control Activities."

Trap-scouting began in 1931, with the first beetle finds being recorded in Augusta and Savannah in 1936. 12 of the 220 areas since surveyed have yielded beetles. Present infestations exist in North Atlanta, Atlanta Airport, Austell, and Dahlonega. The program is a joint project of the Ga. Dept. of Entomology and the U. S. BEPQ.

17. F. R. Blackwell, BEPQ, Tifton, discussed "Recent Developments and Prospects in Sweet Potato Weevil Control in Georgia." He pointed out that of the total 871 properties found infested since 1945, 532 have been released from quarantine, leaving 339 still with active infestations. 102 of these are in Coffee County. The infestations are found in 19 counties in the Southern and Southwestern parts of the state. He believes prospects for control are brighter than in several years.

18. C. H. Alden, State Dept. of Entomology, Atlanta, spoke on "Bee Inspection and Certification." As late as 1935, 20 per cent of the bees inspected were diseased. In 1950, less than 1 per cent were diseased. 75,000 of the 200,000 resident colonies were inspected as well as 30,000 colonies of migratory beekeepers. Over 4,000,000 pounds of honey, 400,000 pounds of package bees, and 100,000 queens are produced annually in Georgia.

19. R. N. Dopson, BEPQ, Houston, Texas, described the "Transit Inspection" of citrus cotton, nursery stock, mail, express, freight, etc. Eight federal and two state quarantines are enforced. To the 13 stations, over 1200 violations were reported in 1950.

20. W. G. Bruce, BEPQ, Savannah, gave a "Report of Activities Conducted in Savannah by the Division of Insects Affecting Man and Animals." He listed several projects in progress, *i.e.*, household ant control, moth-proofing, preventing the infestation of packaged foods, house fly and deer fly control, the imported fire ant, and livestock ectoparasites.

21. F. E. Allison, California Spray Chemical Corporation, Tifton, presented a technicolor reel on "Cotton Insects" by the Anderson-Clayton Company of Houston, Texas.

In the final business meeting, the report of the Auditing Committee endorsing the Treasurer's Report was on motion approved.

The Resolutions Committee reported as follows:

"Be it resolved that the Georgia Entomological Society hereby express its appreciation to Abraham Baldwin College and to President G. P. Donaldson for use of the institution's facilities in holding the annual meeting of the Society on March 9–10, 1951 and to President Donaldson for his cordial and delightful welcome address.

"Be it further resolved that the Georgia Entomological Society hereby express its appreciation to the California Spray Chemical Corporation and to Mr. F. E. Allison for furnishing the fine banquet and excellent entertainment to members of the Society and their families on Friday evening, March 9, 1951.

"And be it further resolved that a copy of these resolutions be sent to the foregoing as an expression of appreciation for the facilities and entertainment furnished to the Georgia Entomological Society during its Annual Meeting on March 9–10, 1951.

"Be it resolved that acknowledgement be made of a telegram received from Vice-President Thomas Gunn, U. S. Navy, Patuxent, Maryland, expressing regret that unalterable circumstances prevented his attendance at the Annual Meeting of the Georgia Entomological Society on March 9–10, 1951.

"Be it resolved that the Georgia Entomological Society express its thanks to President G. G. Rohwer and other officers of the Society and to the local Committee on Arrangements, consisting of F. E. Allison, Chm., T. J. Ratcliffe, and P. M. Gilmer, for their untiring efforts, splendid leadership and services during the past year and for formulating a comprehensive program which has contributed materially to the fine attendance at the fifteenth annual meeting."

The report was on motion approved.

W. G. Bruce, BEPQ, Savannah, was elected president and W. F. Turner, BEPQ, Fort Valley, Vice-President.

Mr. O. I. Snapp urged that all members of the Georgia Entomological Society should be affiliated with at least one of the national entomological societies. He also suggested that the members be ready to propose at the next meeting some useful investment of the Society's funds.

The Secretary was on motion authorized to have Society letterheads printed and the Executive Committee was instructed (on motion also) to arrange for holding the 1952 meetings in Savannah in early March.

President Bruce then appointed a Membership Committee consisting of O. I. Snapp, Chm., G. G. Rohwer, and J. J. Paul.

Respectfully submitted,
HORACE O. LUND
Secretary-Treasurer

IN MEMORIAM

Henry Josef Quayle
1876-1951

Henry Josef Quayle was born April 29, 1876 on the Isle of Man and died October 24, 1951 at Riverside, California. In his early boyhood he came to the United States with his parents who settled in Champaign, Illinois in 1880. He was educated in the public schools of Champaign and then was graduated from the University of Illinois in 1903. Immediately after this he accepted the position of Assistant in Entomology in the University of California. During 1905–1906, Quayle was instructor in Zoology at Iowa State College. During 1906 he returned to University of California as Assistant Professor of Entomology. Later, he became Professor of Entomology and Chairman of the Division of Entomology at the Citrus Experiment Station, Riverside. He continued to serve here until his retirement in 1943. He received the degree of Master of Science from the University of California in 1911.

Professor Quayle was a pioneer investigator in several important fields of entomology. During the first decade of his research work the seriousness of the scale insects on citrus crops in California was becoming generally apparent. He worked with effective enthusiasm in studying the life history of such scale insects and determining means of controlling these pests. Many of his studies were basic to the practice of controlling scale insects by fumigation.

He was among the first to detect the development of resistance in populations of certain scale insects to treatment by fumigation with hydrocyanic acid gas. The results of his original work published in 1916 met with more skepticism than acceptance among many entomologists for several years thereafter. His subsequent investigations, however, proved the validity of his original observations and during the next decade it became generally apparent that Quayle had made a fundamental advance and had raised the profession of entomology to a new horizon in the study of insect control measures.

Professor Quayle recognized the possible threat of the Mediterranean fruit fly to the fruit industry of California. With this pest firmly established close at hand in the Hawaiian Islands, he began to study this insect pest during the early years of his services in California. This finally led to his being loaned for the year in 1929–30 to the United States Department of Agriculture to make a survey of the Mediterranean fruit fly problem in southern Europe, and northern and southern Africa. At this time when the fly had become established in Florida, Quayle's knowledge of the insect became invaluable to that state and the rest of the country in eradicating the pest from the United States.

Professor Quayle was recognized as a world authority on insects of such subtropical areas as California, Australia and the Mediterranean countries. In the course of his studies he made three trips around the world and contributed much to his profession in Spain, Italy, Australia, northern and southern Africa.

The climax of his career in the field of entomology was the publication of his book in 1938 entitled *Insects of Citrus and Other Subtropical Fruits*. This very scholarly treatise has been widely used all over the world where citrus crops are grown. It will be a lasting monument to his lifetime of service in his chosen field of study.

HENRY JOSEF QUAYLE

Professor Quayle was a genial and lovable coworker who had the respect and affection of many people in this state and elsewhere. The young men who were privileged to work with him appreciated the confidence he showed in them and the liberal and generous policy he always followed in guiding their efforts. He served the University of California with distinction throughout a long and useful life and will be long remembered with affection, as a gentleman and a scholar.

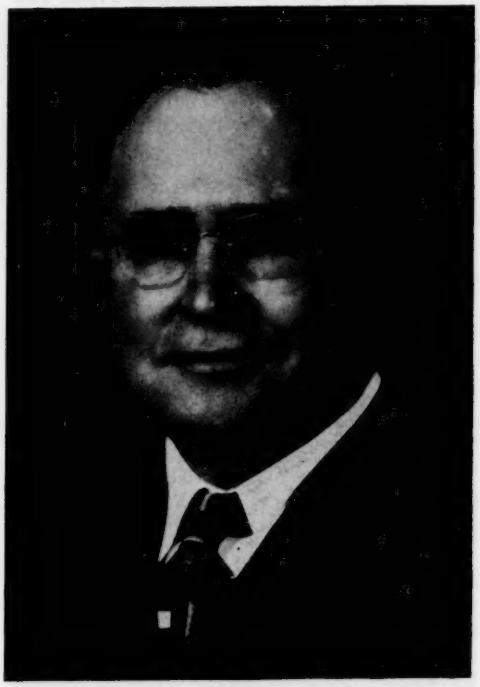
HARRY S. SMITH
A. M. BOYCE
L. D. BATCHELOR

DR. MOTE RETIRES

Dr. Don C. Mote has announced his retirement, effective July 1, 1952, as head of Entomology at Oregon State College, Corvallis, at the end of the Current fiscal year, June 30, 1952. Dr. Mote will be succeeded by Dr. Paul O. Ritcher who moves at that time to Oregon from Raleigh, North Carolina.

William Esco Anderson
August 26, 1892-April 18, 1952

Mr. W. E. Anderson died April 18, 1952, in the Baton Rouge General Hospital. He was stricken April 11 while enroute to his Department's Livestock Diagnostic laboratory. His passing took from public life an official whose unquestioned integrity and honesty will be sincerely missed, not only by the



WILLIAM ESCO ANDERSON

farmers, stockmen and others interested in Agriculture, but by many others who had come in contact with him during his 36 years of public service.

Mr. Anderson was an entomologist by training and practice, having served in this capacity 32 years before being elected Commissioner of Agriculture and Immigration. He began work with the Agricultural Experiment Station of the Louisiana State University and the Bureau of Plant Industry, United States Department of Agriculture May 1, 1916, in citrus canker eradication and inspection work. In 1920, all regulatory work was transfered from under the Agricultural Experiment Station to the State Department of Agriculture and Immigration at which time he was appointed State Entomologist, in which position he served 28 years.

As State Entomologist the highlights of his career included campaigns against such animal and plant enemies as the cattle tick, citrus canker, pink bollworm, mosquitoes, Sugarcane borer, sweetpotato weevil, white-fringed beetle and American foulbrood. In 1927, following a disastrous Mississippi River flood, he headed efforts to rehabilitate beekeeping in the flooded areas. The quarantines he imposed for the good of Louisiana agriculture were strictly and fairly enforced despite the opposition at times of affected groups. His interest was always to serve Louisiana and its people to the best of his ability.

In 1948, Mr. Anderson was elected Commissioner of Agriculture and Immigration, and had been nominated, without opposition, for a second term of four years. After his election to the office of Commissioner, the Legislature placed all of the States agricultural commissions, boards, and similar agencies under his supervision. These included the Weekly Market Bulletin, Seed Testing laboratory, State, District and Parish Fairs and Festivals, State Exhibit Building at Shreveport and the Livestock Sanitary Board; Divisions of Immigration, Agricultural Chemistry, Cotton Classification, Regulatory Entomology and Milk Testing; Commissions of Anhydrous Ammonia, Warehouses, Sweetpotato Advertising and Development, Livestock Branding, Weights and Measures, Pest Control, Horticulture, Seed, and Market.

Positions of honor included, President of the Louisiana Beekeepers Association, Chairman of the Cotton States Entomologists and the Southern Plant Board, Honorary Star Farmer of Louisiana Chapter of Future Farmers of America, Honorary member of American Farm Bureau Federation. At the time of his death, he was Vice-president of the Association of Southern Commissioners of Agriculture.

Mr. Anderson was born, August 26, 1892 in Tangipahoa Parish, Louisiana. He received the degree of Bachelor of Science from Mississippi State College in 1916, and a Master of Science degree from the Louisiana State University, Agricultural and Mechanical College in 1933. He is survived by his wife, Mrs. Natalie (Perez) Anderson.

GUY E. CARPENTER

Mr. Guy E. Carpenter, one of the younger members of the Association, was killed in a plane accident in Texas in December, 1951.

Mr. Carpenter was a member of the staff stationed at Lubbock, Texas.